PRESCRIBED FIRE AND SMOKE MANAGEMENT IN THE SOUTH:

Conference Proceedings

September 12-14, 1984
Atlanta, Georgia

Dale D. Wade, Compiler

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Because of Hurricane Diane, the services of North Carolina State Forester H.J. "Boe" Green and John Shepherd of his staff were required in their home State. Leonard Kilian, South Carolina State Forester, and Joe Clayton, USDA Forest Service R-8, volunteered to give their respective presentations. The Planning Committee expresses its appreciation to the scheduled speakers, moderators, group leaders, and attendees who together made the conference a success. Thanks also to the exhibitors, to General Electric Corporation for a donation, and to Ken Hulick of the Chattahoochee River National Recreation Area who organized an evening raft float.

Committee Membership

Planning Committee: Gordon Lewis, James Lunsford, Hugh Mobley, J. Hugh Ryan, and Deborah Williams. Dale Wade and Thomas Ellis, Cochairmen.

Technical Program Committee: Thomas Ellis, Gordon Lewis, James Lunsford, Hugh Mobley, J. Hugh Ryan, and Deborah Williams. Dale Wade, Chairman.

Local Arrangements Committee: Betty Bush, Gordon Lewis, J. Hugh Ryan, Dale Wade, and Deborah Williams. James Lunsford, Chairman.

Finance Committee: James Lunsford, Hugh Mobley, and J. Hugh Ryan. Dale Wade, Chairman.

Publication Committee: Mary Ann Bennett and Robert Biesterfeldt. Dale Wade, Chairman.

FOREWORD

The deliberate application of fire to produce desired wild-land benefits has evolved through the centuries into the art of prescription burning. Southern resource managers became expert at applying this art and practiced it for decades with few operational constraints. However, as the available land base shrank and management became more intensive, the value of these resources along with the costs of tending and protecting them skyrocketed. These increases have in turn necessitated an increase in the skill and sophistication required to scientifically administer fire treatments. As the South becomes more urban and its environmental values change, traditional fire and smoke management practices are being reevaluated. The benefits of underburning are also now being heralded in many other regions of North America where, 10 years ago, fire exclusion was the goal. All too often the overzealous application of this tool without adequate training and/or due regard to natural and human considerations has resulted in news media events which have had far-reaching implications on our ability to efficiently use fire.

Factors such as the above led to the decision to hold a symposium and workshop to document the current prescribed fire and smoke management state of the art and to describe emerging problem areas. Besides the ubiquitous objectives of information exchange and continuing education, the conference was designed to attract an experienced yet diverse group of prescribed burners, supervisors, managers, and policy makers who would jointly identify the most serious current and near-future problems, unknowns, and ambiguities regarding the use of fire in the South.

The Planning Committee attempted to hold conference attendance to a size that would allow working group leaders the latitude needed to encourage full participation while maintaining a productive atmosphere. The 150 attendees came from all management levels representing 18 private companies, 10 State agencies, 6 Federal agencies, 7 universities, 5 consultants, and a nonprofit wild-land conservation group.

Session I comprises invited papers that summarize current southern fire management practices and describe emerging methodology and technology. These papers should prove to be an excellent source book for people desiring an overview of fire use in the South during the 1980's. Session II mirrors the needs of a wide cross section of users who will ensure that the Southern Forest Fire Laboratory maintains the leadership role in prescribed fire research it has acquired since its inception 25 years ago.

The papers were submitted camera-ready, which greatly facilitated the work of the Publication Committee; please overlook the minor inconsistencies in the format caused by this procedure.

D.D.W.

KEYNOTE ADDRESS

PRESCRIBED FIRE AND SMOKE MANAGEMENT IN THE SOUTH

Benton H. Box [1/]

I consider this a distinct honor to be included on such an outstanding program which will investigate all of the aspects of prescribed burning and smoke management as they affect the environment, as well as what can and should be done to better use this most important tool in southern forestry.

Historical evidence points out that fire has been an important part of the American Indians' life style as well as that of the early Europeans who settled on this continent. They used fire as a tool in their daily lives and had no concerns about setting fires or putting them out. In fact, they often set fires to clear underbrush, to open up the forest for better travel, to drive game, to destroy snakes, or to aid in the production of useful plants or crops. These frequent fires in the forests of the Southeast which occurred over long periods of time have been recognized by ecologists (Oosting 1942, Braun 1950, Cooper 1961) as the principal reason for the subclimax forest communities (mainly the pine types) throughout the region. Hansbrough (1963) reported that stockmen in the wire grass country of the South have used fire to encourage grass for cattle since the introduction of domestic herds in the 1770's. So, fire has been an important part of the scene in the South for a long time, and it has been only in recent times that woods burning has become defined by some people as deviant behavior. These "uncontrolled" burns have become a part of the daily problems faced by a host of state foresters. In this regard, a story is told about the serious illness of an old timer in one of the rural areas of Louisiana. Seems he was about to die and all his children had been called to his bedside. One of his sons asked the father if there was anything he could do for him. He said, "Yes, son. I just want to smell the woods burn one more time." I'm afraid in the area I grew up in back in Louisiana, there was more truth than fiction to the story.

I am pleased that both prescribed burning and smoke management are addressed in this conference. Smoke management was defined by Dieterich (1971) as "a unified effort to eliminate the objectionable characteristics of smoke through improved burning techniques, recognition of optimum weather conditions for burning, and observance of smoke-sensitive areas that would be adversely affected by reduced visibility." When you dissect that definition, we are saying in effect that we must be careful in using this tool; otherwise, the public will cry out with such a loud voice that the Environmental Protection Agency might just limit its use. This, of course, would be most detrimental to our collective efforts.

In regard to the public's attitude toward prescribed fire, Jim Montgomery (1976) of the Southern Forest Institute indicated that the most recent research on the subject shows that 7 out of 10 people are aware that fire is used as a tool in forest management. Also, 7.3% are against using fires as a tool for

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1/ Dean, College of Forest and Recreation Resources, Clemson University.

any reason. One out of four said that fires should be started only under the most necessary circumstances. The most encouraging point of the survey came when two-thirds of the public interviewed believed that fires should be used whenever the forester's judgement determines it necessary. He pointed out that, lest we get caught up in the euphoria of these positive statements, there was an underlying concern listed by those surveyed as to the ecological impact of fire, whether wild or prescribed. This gets us back down to earth and, more particularly, points up the importance of the public's concern about particulates in the atmosphere and their effects on visibility, as well as other potential problems to flora or fauna that could arise from poorly planned and/or executed burning.

According to McMahon (1981) EPA moderated its concerns about the impairment of visibility in areas such as Class I, which includes international parks, national wilderness areas, and both national and memorial parks, in its May 1980 ruling which stated:

"EPA recognizes that prescribed fire is an ecologically sound forest and range management tool used both inside and outside Class I areas. The Agency does not intend that prescribed burningbe eliminated or unnecessarily restricted, but rather, that its impacts on visibility be reduced where feasible and appropriate. Prescribed burning is a necessary part of land management but EPA believes there are techniques to limit its effect on visibility."

So, we need to be very mindful of the public's perception and reactions to the use of prescribed burning. While public attitude is generally favorable toward prescribed burning at this point in time, it is possible for the tide to turn very quickly through some adverse public reaction based upon the emotions of the moment (e.g., the 1980 Mack Lake prescribed fire in Michigan which got out of hand.) My advice to each practitioner is "be cautious." Pick the most favorable weather and fuel conditions so that prescribed burning can be accomplished with the greatest efficiency and effective smoke dispersion.

As a young forester, I was quite anxious to incorporate prescribed burning into our forest management program. An old timer who worked on my crew gave me some sage advice when he said, "Be careful. The only time that fire is under control is before you strike the match." The longer I worked with him, the more I appreciated what he had to say about burning since most of his experience had come through the school of hard knocks trying to put out fires that others had set.

The Society of American Foresters in 1980 certainly recognized the importance of smoke management as it put together its policy statement which succinctly states the following important points:

"Prescribed burning does introduce emissions into the atmosphere. Through smoke management, however, such emissions can be minimized and their effects lessened by burning under appropriate fuel conditions and when the atmospheric patterns promote dispersion. In some circumstances, prescribed burning may result in a decline in air pollution by reducing the size and intensity of wildfires. When utilization of potential fuels is economically possible, it is preferable to burning as a means of reducing hazard accumulation of fuel."

This SAF policy statement thus looks upon prescribed burning as having some problems, but at the same time, it is an excellent tool with many inherent benefits that should be kept available to the forester.

In recounting the early history of wildfires and prescribed burning, Riebold (1971) left little doubt that the South was the birthplace for prescribed burning. Early researchers recognized its potential for the purpose of fuel reduction, hardwood control, site preparation, and disease control. It was not until the early 1930's that the value of prescribed fire for developing and maintaining vegetation control for wildlife habitat was recognized. But also, and more importantly, many forest trees and other vegetation have adapted to periodic fire.

The initial acceptance of prescribed burning by foresters seemed to be tied to favorable research results in the longleaf pine forest type, according to Riebold (1971). It was not until later that slash, loblolly, and shortleaf pine forests were burned with any degree of regularity. This reluctance was based in part on the fear of combining prescribed fire with the then prevalent practice of selection cutting in the slash, loblolly, and shortleaf pine types. Also, many of these foresters had grownup in areas which were hot beds for arsonists, and they were not too inclined toward relinquishing ground gained by fire exclusion. So, prescribed burning has had to wage an uphill battle to become an acceptable forest practice in the South. We still have a lot to learn. This is why meetings such as this are so important. They give us an opportunity to take a look back into the past, to assess our present situation, and to direct our attention toward the needs of the future.

Periodically we should review where we are in solving our problems relative to prescribed burning and smoke management. In this regard, the SAF established certain research needs in its position paper on prescribed burning (1980), including:

A. Effects of fire on forest and range ecosystems and soil nutrients and structure need additional study.
B. Intensified research is also necessary to evaluate the cost and benefits of prescribed burning for particular management purposes under various conditions.
C. More precise knowledge is needed on the effects of weather and topography on burning cost, on probability of prescribed fires escaping, and on the risk of damage if escape occurs.
D. Quantitative information should also be obtained on how prescribed burning affects air quality and production of water, forage, timber, and wildlife habitat.
E. Study the effects or hazards of soil erosion and other damage from wildfire.
F. Evaluate fire protection cost in general.

We might ask ourselves how are we progressing on this list as well as what needs to be added to the list.

One thing that comes to mind is a possible adverse change in the public's attitude toward prescribed burning. While this attitude seems to be favorable at the moment, it could change and we could find ourselves defending the right to use prescribed burning as a management tool. Hence, I feel we should immediately initiate an effort to educate the public on all aspects of prescribed burning. This could be done by openly and truthfully expressing its merits. Because when we evaluate the pros and cons, prescribed fire still emerges as a sound economic and ecological practice which is currently widely accepted. Let's build upon this idea by developing a tactical plan in concert with communication experts who know how to effectively reach all audiences. A possible scenario would be to:

A. Determine what the local opinion is toward the use of this tool
B. Select an audience to which to direct your messages
C. Determine the best **approach(es)** in light of the self interest of the particular audience
D. Get the message(s) across before the problem reaches an epidemic proportion, or heats up as an issue.

After Montgomery (1976)

If we wait until the public outcry causes people to take sides, then we have compounded our problem. This approach could be augmented by positive articles on the use of prescribed fire in selected media across the South as well as feature stories, talk shows on radio and television, and so forth. We also could utilize effectively "show me trips" for selected leaders such as editors, legislators, and others who could become our allies after they have been educated. And, of course, we need to continue to educate ourselves. Many foresters are uncomfortable dealing with any controversial issue. It will behoove us to encourage as many foresters as possible to speak up on this subject in a positive way to the various audiences that they have the opportunity to address.

Of course, it is well for us to remind all foresters who are using prescribed burning as a tool to be very careful in selecting the time, weather conditions, and locations for burning because smoke management and fire containment are two of the most important aspects of burning faced by foresters. It is when we let our guard down in these two primary areas that problems emerge.

In the February 1984 issue of the Journal of Forestry, Von Johnson (1984) describes the managerial anxieties associated with burning, the professional controversies that often crop up, and the technological ambiguities associated with the use of fire by practitioners. One statement which caught my eye in this article was:

"With risk and regulations rising, foresters would no longer have reason to burn--if it weren't for the benefits."

With these thoughts in mind, we may very well be coming to a crossroads which will require us as a group to defend this important forestry practice. The detente or peaceful coexistence that we now enjoy with the environmental community and others could quickly erode or fade away if concerns for air pollution, health hazards, and personal well-being become emotional issues. I would urge that, with this as a possibility, the forestry profession undertake a broad public relations/educational effort that would build a solid foundation for foresters to continue to use this important tool. This planned campaign would allow us to counteract or minimize possible adverse publicity. The effectiveness and success of our efforts could determine the future of prescribed burning in the South.

Thank you very much.

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SESSION I

Prescribed Fire and Smoke Management Overviews

PRESCRIBED FIRE AND SMOKE MANAGEMENT IN TEXAS, LOUISIANA AND MISSISSIPPI

Bruce R. Miles [1/]

Abstract. -- The state forestry agencies in Louisiana, Mississippi and Texas experience the same problems in training, program delivery and smoke management. Enforcement and coordination with federal, state and private landowners becomes increasingly important as smoke management comes under closer scrutiny.

In Texas we prescribe burn approximately 200,000 acres annually, Mississippi estimates 250-350,000 acres annual, while Louisiana reports 450,000. Of this the Louisiana Forestry Commission does 40,000 acres, industry 350,000 and the USFS, 54,000 acres. In Texas, the N.F. burns an estimated 60,000 acres annually, industry 125,000 and private landowners about 20,000 acres. This latter figure, private landowners, is done by the agency's personnel. It is about half of what we target in Texas and 25% of what we would like to do. It is a minute portion of what needs to be done. Prescribed burning is the most important, most wanted and least available service that our agency delivers.

Monitoring prescription burning is the only thing more difficult than getting the burning done. Mississippi requires a burning permit issued under the authority of the State Bureau of Pollution Control, but from the MFC. The bureau has enforcement responsibility. The regulations are not strictly enforced. Mississippi does not have a specific smoke management program other than the burning permit system. Air quality and mixing elements, as determined by the Jackson based Weather Bureau determine the issuance of burning permits.

Louisiana likewise is guided by Weather Bureau reports burning under green and yellow conditions only. The agency is also governed by the Louisiana Environmental Control Commission regarding air quality.

In Texas the agency in cooperation with the Texas Air Control Board monitors the occurrence of prescribed burn. This requires the burn initiator to advise the TFS to report the date and time the burn will start and be completed. If there is a violation or complaint reported to the TACB, the Texas Forest Service is required to relay the information on the specific burn to the TACB. The TACB may then instruct the TFS to advise the burning supervisor to extinguish the fire. Failure to have reported the burn initially creates more problems with the TACB and forest landowners. Major forest industry recognizes this and has been diligent about reporting planned burns. Should weather conditions suggest poor burning conditions, i.e., inversion layer, the agency informs the industry accordingly.

1/ State Forester, Texas

Paper presented at the Conference on Prescribed Fire and Smoke Management in the South. Atlanta GA. Sept.12-14,1984.

Major landowners in Texas cooperate in a voluntary moratorium when burning conditions reach a dangerous level. This not only causes frustration with the industrial community but also within the agency. The personnel who are burning for our forest management chief are the same ones fighting fire for the fire control chief. This dual responsibility is more than the employee himself can often satisfy and is completely unacceptable to either staff member.

Texas has a set of smoke management guidelines developed cooperatively between the TFS and the TACB. These guidelines determine weather variables and thus whether it is wise to burn. The formal communication program with forest industry provides weather information that may affect smoke dispersion as well as fire behavior. Advisories against burning are communicated to the cooperator. The Air Control Board's regulations are fairly specific as to where burning may or may not be done and what constitutes a violation. The agency itself has a smoke management program for its inner agency burns.

All three state agencies offer turn key prescribed burning work. Texas does burning for other state agencies, for a fee, such as the General Land Office and the Texas Parks and Wildlife Department.

By necessity all three have some type of liability coverage. Mississippi relies on "Sovereign Immunity" doctrine to escape liability. While this was tested and upheld in the state court several years ago, the Commission does not expect it to continue much longer.

Louisiana has a liability insurance of $10,000. Employees are indemnified by Louisiana statute. The insurance company thus far has paid all claims to the landowner's satisfaction.

The state of Texas provides liability protection to its employees up to $100,000 per individual for personal injury or death and up to $10,000 for property damage. Additionally, the agency carries a policy with a private carrier for coverage from $10,000 to $100,000 per occurrence for property damage. We have not yet been taken to court but have paid for some fence posts, heirloom quilts (left in pastures) and peach trees.

Texas, Louisiana and Mississippi all have training programs on prescription burning. All share these training opportunities with industry, SCS and other cooperators. The Society of American Foresters has also conducted a training program within the state of Texas in the past. We get continued requests from industry for this type of training for new employees. We are currently developing a training program for supervisors charged with the responsibility of developing prescribed burning plans and supervising others.

The bottom line, like square one, is the most populated space on earth. It is that we are not burning as much as we'd like to or need to do. In Texas our MBO for 1984 was 43,350 acres. To date we have accomplished 28,000 acres. Weather and skilled manpower are the limiting factors. Both Louisiana and Mississippi unanimously agree with this assessment. It is difficult to train and equip a seasonal work force based upon a suitable weather situation. We have private foresters and other contractors that take issue with competition in the areas of timber marking, tree planting and T.S.I. - areas the the agency could utilize a dependable seasonal work force during non-burning periods. Yet, these same private contractors want the prescribe burning service provided by the state.

An alternative is to train private contractors to do this work with labor used in tree planting, etc. The obstacle is high insurance premiums and risk associated with burning. A second concern is the high cost of specialized fire fighting equipment. Some contractors have suggested sub-contracting for the state under its umbrella of insurance protection. Our attorneys have refused to entertain this arrangement.

What are the most serious problems, unknowns or ambiquities affecting the use of prescribed burning in the states? All of the above, viz, liability, smoke management, favorable weather and the hurdle of training or otherwise acquiring a trained seasonal work force that conduct a large volume of prescribed burning during a short period of time.

OVERVIEW OF PRESCRIBED BURNING AND SMOKE MANAGEMENT PROGRAMS AND PROBLEMS IN ALABAMA, FLORIDA AND GEORGIA

C. W. "Bill" Mood+'

METHODS USED TO ADMINISTER OR MONITOR PROGRAM

Alabama

Alabama has a permit system for all open burning in rural areas. Prior authorization of the Alabama Forestry Commission is required. Authorization is given by telephone or in person and a permit number is assigned. All information required; such as name, address, telephone number, size of burn, etc. is logged and made a permanent record. Permits are issued for one day only except on the weekend. They can be issued on Friday for the weekend, however, during periods when the district dispatch center is closed.

Florida

Florida has an authorization system similar to Alabama. However, they do not authorize burning for over one day. This authority is also delegated to some fire departments.

Georgia

Georgia has a "notification of intent to burn" law. The Georgia Forestry Commission has to be notified before any outdoor burning is initiated.

CRITERIA FOR ISSUING PERMIT

Alabama

In Alabama, the following criteria must be met:

a) The person requesting the permit must have adequate tools, equipment and manpower to stay with and control the fire during the entire burning period.

b) The person requesting the permit is responsible to keep the fire confined.

c) In no case will the person requesting the permit allow the fire to be unattended until it is dead out.

1/ State Forester, Alabama Forestry Commission, Montgomery, AL

Paper presented at the Conference on Prescribed Fire and Smoke Management in the South. Atlanta GA. Sept. 12-14, 1984

Florida

The same criteria apply in Florida. In addition, firelines adequate to control fire are also required.

ENFORCEMENT

Florida and Alabama

If any of the above criteria are not met, if the fire escapes or if authorization to burn was not secured, the person responsible can be issued a warning or be cited. In both states, this is a Class B misdemeanor.

SITUATIONS WHEN NOT ISSUED

Alabama

The Commission cannot legally deny permission to burn except when the State Forester has issued a "Fire Alert" for that particular county. If other than "forestry or agricultural" burning certain air quality regulations do apply, although the Commission has no authority in enforcing these regulations.

Florida

The Division of Forestry has complete authority to stop issuing permits according to fire danger or air quality. When fire danger is high, authorization for more hazardous type burns are issued only after an on-site inspection.

Georgia

Georgia has no authorization or enforcement powers. Restraint is sought on a voluntary basis when fire danger is high.

Amount of prescription burning done during average year

Type	Acres		
	Alabama (1983)	Florida (1983)	Georgia
Forestland	878,970	2,808,000	665,000
Agriculture	177,240	1,401,000	451,000
Other	20,310	350,000	---
Total	1,076,520	4,559,000	1,116,000

Florida's permit system has been in place for a few years and is possibly more accurate. These are areas planned to burn and all of the area may not have actually been burned.

SMOKE MANAGEMENT PROGRAM

Alabama

A stagnation index is included as part of the weather forecast as well as visibility, transport winds and mixing height. The person requesting permit is made aware of possible smoke problem if dispersion is poor. Alabama Forestry Commission personnel cannot burn when dispersion potential is very poor.

Florida

Florida also uses a stagnation index and visibility as a criteria for smoke dispersion. Florida can deny issuing permits due to poor dispersion whereas Alabama cannot. A pilot smoke management system will be tested in two districts this winter.

Georgia

Georgia has no specific smoke management program at this time.

PRESCRIBED BURNING SERVICES OFFERED BY STATE

Alabama

Offers fireline plowing and charges are based on average operating cost by the hour for the unit and mileage for the transport. Contract prescribed burning is also offered and charged on acreage basis. Landowner is referred to consultants if such services are available. If the area is forest land, it has to have a forest management plan. A written prescription is also required. The person making the prescription and person in charge of conducting the prescribed burn have to be certified after qualifying in experience and training. To be certified, they have to have had two years fire experience, complete the Forestry Academy (which includes all the basic fire courses), a week of formal training in prescribed burning, the week long Intermediate Fire Behavior course and have experience on at least ten prescribed burns.

Florida

Also does contract burning and firebreak plowing for a charge--much the same as Alabama. A written prescription plan is made and an agreement is executed with the landowner. This service is offered only where private contracting service is not available.

Florida also offers Standby Burning Assistance for a charge. State personnel standby to assist a landowner while he is prescribed burning. The state assumes no responsibility and reserves the right to leave the scene if necessary. Florida also has another type of prescribed burning that is unique. It is called--Prevention Burning:

a) The Florida Division of Forestry and a local governing body can designate portions of a railroad right-of-way as a fire hazard. These areas have to be either burned or the fire hazard reduced in some other way to the satisfaction of the state. The railroad can contract with the Division for burning the right-of-way.

b) The Division of Forestry can prescribe burn private property at the request of the local governing body to reduce the fire hazard--if the landowner does not object. This regulation came about due to the problem of absentee landowners. There is no charge.

   The state can also prescribe burn other landowners land, with written authorization, to reduce occurrence of wildfires. Neither is there a charge for this service.

Georgia

Provides firebreak plowing and on-the-ground assistance in prescribed burning as fire conditions permit. The landowner has to initiate the fire. There is a charge for firebreak plowing but not for standing by or assistance.

LIABILITY

Georgia does not assume responsibility for the burn--only helping the landowner.

Florida assumes liability when they do the burning and state is self-insured.

Alabama has to allow itself to be sued. A bill is pending to protect employees from being sued, by the state assuming responsibility. We feel that by using only fully experienced and qualified personnel to make prescriptions or to conduct prescribed burns will help to protect the Commission and our personnel.

None of the three states have had a court case concerning liability.

TRAINING PROGRAMS

Training (other than their own personnel) has not been a strong area in any of the three states in the past. Florida has offered infrequent courses for industry. Alabama has put on training courses only as requested. (These have increased in the last two years.) Georgia has offered two prescribed fire and smoke management short courses within the past year and plan to continue these on a periodic basis.

IS PRESCRIBED BURNING ON STATE-MANAGED LAND ADEQUATE?

Georgia is current with their burning program. Alabama and Florida are not. Florida states weather is the main reason they are not current. Alabama's problem is lack of trained personnel but we expect to catch up with our burning program by next year. Alabama manages very little forest land and consequently this is not a big problem for us.

MOST SERIOUS PROBLEMS AFFECTING THE USE OF PRESCRIBED FIRE

Georgia

Georgia listed smoke on highways as one of their biggest problems. It has led to several fatalities over the last few years.

Florida

Florida listed not enough days to burn and smoke management as an ever-increasing problem. They have had three major highway tragedies in the last year.

Alabama

These two (smoke on highways and not enough days) are certainly Alabama's major problems as well. We would also add lack of qualified people as a third major problem. This is especially true with industry. We have two specific problems or needs that in turn would help to reduce the first three problems.

These are:

--No "Smoke Management Guideline" for logging debris such as we have for understory burning. The burning of logging debris produces much more of a problem and we need a starting place in learning how to cope with it.

--Lack of a system to predict scorch height (or possible damage to overstory) is also a problem. Such guidelines, would make it much easier to train people--and they could learn to plan and conduct quality prescribed burns much quicker.

A SUMMARY OF PRESCRIBED BURNING AND SMOKE MANAGEMENT ACTIVITIES IN VIRGINIA, NORTH CAROLINA AND SOUTH CAROLINA

Horace J. "Boe" Green[1/]

Prescribed fire is an important forestry tool in the states of Virginia, North Carolina, and South Carolina. It is used primarily for hazard reduction, site preparation and other types of silvicultural purposes. Burning in all three states is done under permit with the state forestry agency, and all three states make use of a voluntary Smoke Management Plan. The Smoke Management Plan links the state agency responsible for air pollution control very closely with the state forestry agency. Forestry burning is generally exempt from control under the air pollution control agency, unless an extreme air stagnation condition develops -- In that case all outside burning is usually forbidden.

All the land prescribe burned in these three states would be classed as forest land. The acreage burned increases from North to South by State. Virginia burns a little less than 50,000 acres; North Carolina burns a little less than 200,000 acres; and South Carolina burns a little over 500,000 acres. The burning in South Carolina, however, does include some for grazing with very little or none occurring in North Carolina and Virginia for that purpose.

As mentioned earlier, all three states have a voluntary Smoke Management Plan in place. These Plans have been in existence for several years and seem to be doing an adequate job of smoke management. As stated earlier, the Smoke Management Plan in all three states is voluntary and is managed by the state forestry agency. The Plans, in general, limit the amount of fuel to be burned in relation to the ability of the atmosphere to disperse the smoke.

All three states offer prescribed burning services. South Carolina offers full service for burning. Their agency will stand by while the landowner, or his agent, does his own burning. South Carolina charges $3.00 per acre for doing the burning, with additional charges for line construction and transportation of the equipment to the site. For the standby assistance, the Forestry Commission will examine the property, prepare a Plan, and stand by with fire suppression equipment while the burning is being carried out. The charge for this service is $9.00 per hour for stand by, plus transportation cost and line plowing if needed. The landowner may furnish the Plan, but it must be approved by the Commission. North Carolina offers complete burning services for private landowners for hazard reduction, site preparation, and other silvicultural

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1/Director, Division of Forest Resources, NC Dept. of Natural Resources and Community Development, Raleigh.

purposes. A fee is charged for this service, and the fee ranges from about $3.00 to $10.00 per acre depending on the size of the tract burned. Virginia, just this year, received the authority to offer site preparation and hazard reduction burning to landowners if they participated in the burning. Each state has a little different approach for handling the state liability for the burning. South Carolina's liability coverage comes under their state general tort liability insurance. This provides a one million dollar coverage, and the premium cost each year amounts to $8,397. North Carolina's liability also comes under the tort claim with an amount of $100,000 per incident. In addition, all employees in North Carolina who are classed as Law Enforcement Officers have an additional $800,000 individual coverage. Virginia's liability is covered under a 9 million dollar liability policy. None of the systems in these three states have been tested in court.

All three states are providing prescribed fire and smoke management training. Virginia offers in-service standard fire training courses. This training is also offered to forest industry and volunteer fire departments. North Carolina has in-service training also. A statewide prescribed burning and smoke management school was conducted in 1981. Local and regional training has been carried out since that time. South Carolina conducts an annual prescribed burning and smoke management training school at their Sand Hill State Forest. In addition, they are holding smoke management workshops throughout the state for their own personnel and for their cooperators and interested land-owners.

None of the three states are burning as much as they would like. The three main restrictions are the lack of man-power to do the burning in a given day, the number of days when burning can be accomplished, and the limitations caused by smoke management guidelines.

The serious problems relating to prescribed burning relate to the smoke as well as to the fire itself. Several automobile accidents have been related to smoke on highways, and several civil suits have been filed in this regard. In North Carolina, we have also had claims arising from smoke damaging structures as well as their contents. With this in mind, we need more research on how to predict the production and dispersion of smoke. Because of the limited number of days in which we can burn, we need to know more about how to get the optimum amount of burning done while causing little or no damage. Obtaining this optimum also involves the best use of aerial ignition, other firing methods, and a variety of burning techniques. It would also be helpful if we could get people, other than our own agencies, involved in burning. This possibly could be done by consultants, the forest industry, and private contractors.

In summary, prescribed fire is an accepted forest management and hazard reduction tool. Its continued use is necessary if we are to greatly reduce the number of acres lost to wildfire or significantly increase reforestation. There is considerable concern among people who do prescribed problems with smoke. These same people want to optimize the amount of burning done each year. To do the amount of burning that needs to be done with minimum damage we need: 1) better weather forecasting; 2) better information on predicting smoke production and dispersal; 3) good training to insure appropriate use of firing and burning techniques; and 4) maximum use of all resources available in the forestry community to do prescribed burning. A lot of progress has been made in the last decade, but there is still a long ways to go to fill our prescribed burning and smoke management needs.

STATUS OF PRESCRIBED FIRE AND SMOKE MANAGEMENT IN ARKANSAS, KENTUCKY, OKLAHOMA AND TENNESSEE

Roy Ashley

State Forester
Tennessee

It is an honor and pleasure to speak to you today. I am honored because this is the most esteemed group I have ever seen gathered in one place to review current prescribed fire and smoke management practices in the South. It is also my pleasure to be asked to represent those predominantly hardwood states in the region. I do hope the recommendations developed here will have application to our hardwood forests as well as the pine types of the more southern states.

The purpose of my remarks is to provide a current overview of the status of prescribed burning in forestry, in four states. Obviously, I will be more familiar with Tennessee's status than any other state. I must say that I am certainly more comfortable in the overview role, speaking only in generalities rather than in the specifics of prescribed fire. I recently read a very specific definition of prescribed burning that was sixty-one words long. I cannot be that specific with you today.

As those of you who use it regularly know, prescribed fire can be a tool in the hands of the knowledgeable forest manager. It can be used for silviculture purposes. It can also be used to reduce damage from wildfire. However, it is my observation that not all professional foresters are knowledgeable in the proper use of prescribed fire.

Since as foresters we don't always understand prescribed fire and its beneficial uses, we cannot explain the beneficial effects of fire to the public.

Tennessee, like the other states I am representing, which includes Arkansas, Kentucky and Oklahoma, is basically a hardwood state. This fact makes selling the beneficial use of fire even more difficult. For years in Tennessee, our fire prevention efforts have taught the public that hardwoods and fire do not mix. Thus, it is difficult for the public to understand fire as an important tool in forest management---even in the pine types. This public attitude is reflected in several of the answers to the questions presented to the states I am representing.

Paper presented at the Conference on Prescribed Fire and Smoke Management in the South. Atlanta GA. Sept. 12-14, 1984

As the use of -prescribed fire increases, and the benefits become better understood, I predict we will see it used more, even in the predominantly hardwood states like Tennessee. In Tennessee, prescribed fire will slowly carve its niche into forest management activities, particularly in the areas of hazard reduction and wildlife habitat manipulation within pine types.

The wrong use of fire is still prevalent even in the hardwood forests of Tennessee. By that I mean burning the woods to get rid of snakes, chiggers, ticks and to green up the grass. This "wrong use" is also widely practiced in the pine types to our south. It will be a slow process to unravel the good uses from bad uses of prescribed fire. It may be a longer process separating the proper forest types from improper forest types, in which to practice the beneficial use of prescribed fire.

In Tennessee, water quality and soil erosion are high priorities within state government. It is not unusual to sell fire prevention as a way to reduce stream degradation and soil erosion, while at the same time talking about the benefits of prescribed fire. Needless to say, the public sometimes reacts in a confused manner. We need continued training of agency personnel on how to deliver the proper prescribed fire message. I believe this workshop will aid participants in delivering that message. I like the definition of prescribed fire on the inside front cover of A Guide For Prescribed Fire in. Southern Forests.[1] "Prescribed Burning is fire...

- Applied in a skillful manner
- Under exacting weather conditions
- In a definite place
- For a specific purpose
- To achieve (certain) results"

Both professional foresters and the public need to understand this definition.

For the states I represent, the estimated annual use of prescribed fire provides us a benchmark from which to start (Table 1).

Table 1.--The estimated annual use of prescribed fire by State and type of burn.

	Average Annual Acreage	Major Type of Burning
Arkansas	8,900	100% Forest
Kentucky	100	100% Forest
Oklahoma	40,000	50% Forest 50% Range
Tennessee	22,100	100% Forest

[1] A Guide For Prescribed Fire in Southern States, USDA, USFS, Southeast Area State and Private Forestry-2 (1973).

A closer iook at Tennessee's prescribed burning acreages, by landownership class and percent of the total, provides no surprises. Almost three-fourths of the prescribed fire use is by private industry. The second highest category in Tennessee is the prescribed burning of state owned land (Table 2).

Table 2.--Summary of the average estimated prescribed burning acreages by landownership class in Tennessee

Landowner Class	Acreage Burned	Percent Of Total
Federal	2,060	9
State	2,540	11
Private Industry	16,410	74
Small Private Landowner	90	1
Miscellaneous	1,000	5
TOTAL	22,100	100

IMPORTANCE

The importance of prescribed fire to the four states may be somewhat less than sister states to the South. Most of our forestland is hardwood and prescribed fire is not as needed a tool in hardwood as in the pine types. Major demands met by prescribed fire treatment include (a) Hazard Reduction (b) Wildlife Habitat Improvement and Maintenance (c) Grazing Enhancement and (d) Site Preparation.

STATE SYSTEMS AND REGULATIONS

A brief statement of the prescribed fire system and state regulations will provide a better understanding of current emphasis in each state.

Arkansas-The Forestry Commission's reporting system requires that a report be filed in both field and central office on each prescribed burn. Regulations governing prescribed burns in Arkansas are covered under the Air Quality Regulations of the Pollution Control Board.

The Commission does offer site preparation burning for natural and artificial regeneration as part of its service to landowners. Also, hazard reduction burning is practiced, especially in trouble spots along railroads. Approximately ninety miles of railroad and hazard reduction burning are completed in an average year.

Liability claims for prescribed fire losses in Arkansas are reimbursable through the State Claims Commission, although the system has not been tested in court.

Kentucky - Kentucky has no system to authorize or monitor prescribed burns; nor is there a smoke management program. State fire laws do regulate outdoor burning. The Kentucky Division of Forestry offers no prescribed burning services. Since these services are not offered, liability is not an issue. Likewise, there has been no court test connected with prescribed fire.

Oklahoma - In the state's protected region, Oklahoma law requires notification to the Forestry Division of an "intent to burn" four hours prior to ignition. Outside the protected region, no notification is required.

Outside the protected areas, in order for prescribed or controlled burning to be lawful, the person doing the burning shall take reasonable precaution against the spreading of fire to other lands by providing adequate firelines, manpower and fire fighting equipment for the control of such fire, and shall watch over said fire until it is extinguished and shall not permit fire to escape to adjoining land. Oklahoma's air quality guidelines state that prevailing winds must be away from any city or town, the location of the burn must not be adjacent (not within 500 feet upwind) to an occupied residence, initial ignition must be between three hours after sunrise and three hours before sunset and no traffic hazard can be created by the smoke.

The Division offers fireline establishment as the only "on the ground" service in connection with prescribed burning. Foresters do make prescriptions and develop plans for landowners to do their own burning. The SCS is currently increasing their range burning emphasis in Oklahoma. The Division encourages landowners to purchase a liability insurance policy before burning. There has been no court test of the program.

Tennessee - The Division of Forestry uses a permit system to authorize and monitor prescribed burns. Persons are required to have a written permit in their possession at the time of the burn. Permits are good for twenty-four hours only and cannot be written more than twenty-four hours in advance. The permit law is in effect from October 15 to May 15 inclusively and between the hours of midnight and 5 P.M. Burning is permitted between 5 P.M. and midnight from October 15 to May 15 without a permit. Additional state fire laws must be followed. From May 15 to October 15, the remaining state fire laws continue to apply. A permit is required for all burning within 500 feet of woodland or grassland leading to woodland. Railroads and other bonded contractors are exempt from the permit law but not the other fire laws. Tennessee has no smoke management program. Within certain guidelines, burning for agricultural and forestry use is exempt from regulation by state air pollution and water quality laws.

The Division does offer prescribed burning services for a fee. Fees are based on actual cost for personnel and equipment. No overhead costs are computed. A State Board of Claims handles liability claims, although the system has not been tested in the courts.

TRAINING

Training in prescribed fire varies widely among the four states. For our purpose here, a brief statement on each state's training status should suffice.

Arkansas - The Commission has periodic training, approximately every two years, for both state and private foresters.

Kentucky - Kentucky has no training program for prescribed fire or smoke management. However, key field employees are furnished copies of the publication "Southern Forestry Smoke Management Guidebook".

Oklahoma - Oklahoma holds pre-scribed fire workshops each year.

Tennessee - Periodic prescribed fire training is provided, using the USFS prescribed fire and smoke management courses.

BURNING ON STATE-OWNED LANDS

As indicated below, varying degrees of state-owned land is prescribed burned.

Arkansas - Based on current funding, staffing and equipment, Arkansas is burning about all it can handle on state lands. Certain parts of the state has not yet accepted prescribed fire. Also, most of the state is hardwood, where burning is not accepted due to potential damage.

Kentucky - No prescribed burning is utilized on State Managed lands.

Oklahoma - The Oklahoma Division of Forestry has no State Forest lands. However, other state agencies (i.e. wildlife) carry out prescribed burns on their holdings with some regularity. Acreage burned on these areas for wildlife habitat improvement should be increased.

Tennessee - Tennessee is not using prescribed fire to the extent it should on State Forests because:

a) Of public attitudes
b) Management Planning has not been completed
c) Manpower and equipment limitations
d) Limited burning periods

PROBLEMS

The most serious problems, unknowns or ambiguities, affecting the use of prescribed fire in the four states are listed below.

Arkansas - The most serious problems are:

a) Limited burning periods
b) Insufficient equipment and personnel available during burning season
c) Risk of fire escaping
d) Non-acceptance of prescribed fire by public and landowners

Kentucky - The fact that 89% of Kentucky's forestland is hardwood precludes a need or demand for use of prescribed fire.

Oklahoma - The largest unknown is the question of liability. The Forestry Division hopes to increase its prescribed fire activities if the liability issue can be resolved.

Tennessee - Problems, unknowns or ambiguities are:

a) Conflicts with local (county/city) ordinances in urban areas
b) Many Tennesseans do not accept prescribed fire as a management tool.
c) Tennessee is a hardwood state (82%)
d) The liability issue has not been tested and some TDF employees are reluctant to ignite fires.
e) Short burning periods

SUMMARY

It is obvious from the varying levels of use of prescribed fire in the hardwood oriented states that it is not widely considered as a necessity for a viable forest management program. It is equally clear that many people recognize that this tool is neither desirable or needed in most of the hardwood forests.

However, let me reemphasize my own personal belief that the use of prescribed fire will continue to increase in these predominantly hardwood states. Prescribed fire does have a place in the improved management of the southern forests.

The extend to which prescribed fire will ultimately be used in Arkansas, Kentucky, Oklahoma and Tennessee may eventually be decided based on non-forestry objectives. Public attitudes will be slow to change. All fire in these states may continue to be viewed, by a vocal minority, from the standpoint of damage to any tree. However, air and water quality and soil erosion considerations must also be evaluated. Before it reaches its legitimate potential, prescribed fire may receive lengthy debate based on these issues.

A WESTVACO PERSPECTIVE ON PRESCRIBED BURNING AND SMOKE MANAGEMENT

William D. Baughman[1/]

Abstract.--Prescribed burning is a vital tool in the management of industrial pine plantations. New techniques and tools such as the use of helicopters in aerial ignition have facilitated the use of fire in younger stands, while permitting more acreage to be treated in a given time period. The management of smoke from prescribed burning is a key factor in the continued use of fire. Improved weather forecasting and further refinement of equipment and burning techniques are needed. Adherence to voluntary smoke management guidelines is the best way to insure the availability of prescribed burning as a forest management tool.

In South Carolina about 513,000 acres are being burned annually. About 4% of this is to improve grazing, 12% is for site prep, 23% for wildlife habitat improvement and 61% is to reduce the hazard of wildfire. Who's doing the burning? Of that half million acres burned annually, only 26% (133,000 acres) is burned by industry. That's an important point that I want to come back to later.

The history of prescribed fire at Westvaco goes back more than 30 years. It was 1952 when Southern Woodlands began a formal program of prescribed burning. Since that time we've burned more than 1.4 million acres. That's the equivalent of having treated our entire woodlands three times in the last 30 years. Our primary goal in prescribed burning is to eliminate understory fuel accumulations that pose a serious threat of wildfire.

How much of a problem is wildfire? In the three years prior to 1952 Southern Woodlands had 20,000 acres burned by wildfire. In the last few years, even though our ownership is larger than it was in 1952, we've held our wildfire losses to less than 1000 acres annually. Some of that reduction is due to favorable weather, some to improved detection and suppression techniques, but a large part of it is due to the regular "fire proofing" of our timber stands, through the use of prescribed fire. That's an important point to remember. I know of no other way to "fire proof" a timber stand than to remove the bulk of the fuels. The only cost effective way to do that is through the use of prescribed fire. What alternatives exist to prescribed fire as a deterrent to wildfire?

For the last 10 years we've been burning about 50,000 acres annually, basically on a three year cycle. Some stands are burned more often, even yearly where the risk factor is high, while others are burned less often,.

1/ Southern Woodlands Manager, Timberlands Division, Westvaco Corporation, Summerville, SC.

Paper presented at the Conference on Prescribed Fire and Smoke Management in the South. Atlanta GA. Sept. 12-14, 1984

About 95% of the time, the primary purpose of our prescribed burning in established pine stands is to reduce the hazard of wildfire.

Other objectives of our prescribed burning program include hardwood brush control, wildlife management, and improved recreational opportunities. We also use fire to reduce logging residues, normally burning either **windrows** or piles following site preparation, but in our company we do not refer to this as prescribed burning. This accounts for an additional 12 to 15 thousand acres annually over and above the 50,000 acres of established stands burned annually.

From the start of our prescribed burning program in 1952 till the late **70's** all of our firing was done by hand, on the ground. Under a variety of terrain, fuel, and weather conditions we've used all of the commonly accepted firing techniques including head fires, back fires, and flank fires. The drip torch has been the principle tool in hand ignition.

A major change in our burning practices began to evolve in 1979 as we started working with the concept of aerial ignition. In the Coastal Plain of South Carolina we average 30 days of acceptable burning weather each year. This limited time frame, in addition to our own self imposed constraints in the form of smoke management guidelines, meant that we needed to find a way to take advantage of every suitable opportunity to treat both site prep and prescribe burn areas.

We looked at a variety of aerial ignition systems. We ultimately ended up working with a local helicopter service in developing what we consider to be a very good aerial ignition system. It is simple, but still affords us the level of control necessary to achieve the desired results.

This system has done several things for us. We have been able to burn larger blocks using fewer ground personnel and have shortened the time period from ignition to burnout. **We've** been able to prescribe burn younger stands and that has given us additional insurance from the hazard of wildfire.

Using the helicopter we are now burning stands that are only 15 to 20 feet tall; this works out to about an age 6 to 8. By putting the firing lines very close together and closely spacing the drops of jellied gasoline within those lines, the fire burns very rapidly and burns itself out before it has the chance to gain much heat or speed. It results in a classic example of area ignition.

Using the aerial system for burning **windrows** we've been able to ignite more than 50 acres of **windrows** in approximately 5 minutes. In early tests it was our conclusion that we could ignite up to 500 acres per hour with the helicopter under ideal conditions; however, we no longer fire blocks this large at one time because of our adherence to the South Carolina Smoke Management Guidelines.

Benefits of aerial ignition include reduced manpower, increased safety for our ground personnnel, improved production and earlier "fire proofing" of younger or shorter stands.

There has been a great deal of concern about the possibility of damage to stands as a result of prescribed burning, especially from the aerial ignition standpoint. So far that has not been the case for us. We've found that less than 1% of the stands treated with fire have been damaged. Our goal is to scorch no more than 1/3 of the crown, but in the first burn that I described earlier, we are willing to accept more light scorch of the live crown. The trade off is a stand destroyed by wildfire against a stand that is "fire proofed" but with some slight growth loss for that first year.

I mentioned earlier that aerial ignition allows us to burn a large number of acres in a relatively short period of time. One very real advantage of this is that we can accomplish a burn within a time period of known weather conditions, in some cases getting the fire ignited and through total burnout in less than two hours. The disadvantage of this is that we generate large volumes of smoke during that period.

It's my belief that the management or the lack of management of this smoke will ultimately decide whether or not we can continue to use what is a very effective, economically sound, forest management tool.

The Clean Air Act of 1977 accomplished several things. For those of us in forestry it was the impetus to look for ways to improve the quality of our prescribed burning. As a result of the Clean Air Act it became essential that we examine environmental and social impacts of burning, that we weigh the benefits of burning against the costs, not just to us but to those in the communities around us. The Clean Air Act has caused us to examine both the short and long term effects and consequences of burning. I believe that we are better foresters; more responsible corporate citizens as a result of that.

Prior to the start of the 1980-81 burning season, forest industry and the State Forestry Commission officials working through the South Carolina Forestry Association, developed a set of voluntary smoke management guidelines for prescribed and site prep burning. These guidelines are the foundation of a system of self regulation for the forest landowners in South Carolina who use fire as a management tool. There are those who claim that voluntary standards are the first step toward regulation. I disagree with that. There is no doubt in my mind that voluntary regulation, forest landholders applying peer pressure to their contemporaries, is far more effective and will achieve equal if not better results at lower cost than state or federal regulations could ever hope to achieve. I also believe that without effective voluntary constraints, we will end up with legislated regulation.

Someone trying to make a "worst case scenario" could point out that prescribed burning produces toxins - but in fact all combustion of organic substances produces limited amounts of toxic substances. It has been noted by various researchers that the amount of particulates and other emissions resulting from prescribed burning can be significantly lessened in most cases by adjusting how we burn. In almost all cases emissions from prescribed burn fires are less than those from wildfire. Prescribed burning is an oxidation process, quicker, but still similar to the process that occurs in the natural decay of litter on the forest floor. For these reasons I don't believe that emissions are really the primary issue for those concerned with smoke management. The biggest challenge we have to face is the visibility problem on adjoining highways, in nearby subdivisions, and towns, or other smoke sensitive areas.

Let me point out one last fly in the ointment. At the start of my presentation I stated that South Carolina forest industries account for only 26% of the prescribed burning in the state. That means the greatest number of burns are set by private non-industrial landowners. Are these fires supervised by experienced professionals versed in the use of fire as a tool? Do these landowners know about voluntary smoke management?

We have a variety of programs to inform non-industrial landowners about reforestation, but what have we done to let them know about the effective use of prescribed burning, and smoke management?

Voluntary guidelines are not without disadvantages. Using these guidelines we find ourselves with even fewer suitable burning days each year. We've also found that we need more concise, accurate, up-to-date weather information. than we've ever needed before, and that getting such information on a timely basis for localized conditions continues to be a problem. But these negatives must be weighed against the continued availability of prescribed burning as a management tool. We at Westvaco have found ways to still meet our annual prescribed burning goals through the development of improved techniques, and new equipment such as the aerial ignition systems. That kind of growth, that kind of innovation can only serve us well in the coming years.

CONCLUSION

Through self regulation such as voluntary smoke management guidelines we can continue to steer our own course as forest managers. Without such self constraint we can expect to find ourselves in uncharted waters, drifting aimlessly while we argue with government officials over who's hand should be on the tiller.

USE OF PRESCRIBED FIRE ON INDUSTRIAL LANDS IN THE GULF COASTAL PLAIN AND UPLANDS

Richard A. Williams [1/]

Abstract. --The Mid-Continent Division of Georgia-Pacific Corporation uses prescribed fire extensively as a cultural tool in loblolly-shortleaf pine management in the Arkansas, Louisiana, Mississippi region. Fire is used for fuel reduction, site preparation or brush control in areas that foresters determine by ground reconnaisance are best suited for the treatment. Considerable care and planning burns is involved in coordinating with other operations, preventing damage by scorch and in smoke management.

The use of prescribed fire as a silvicultural. tool has been in effect for over half a century in the southern pine region. Restricted primarily to longleaf pine forests at first, its use came into prominence in loblolly-shortleaf forests thirty-five to forty years ago. The even-aged condition of longleaf stands, the fire resistence of the species and the need for control of brownspot disease by burning off diseased needles made controlled fire and longleaf pine highly compatible. In loblolly pine, however, the mixed age condition of the early cutover stands, the species lesser fire resistence and the problems of rougher terrain and varied fuels made foresters highly cautious in using fire.

As the young second growth loblolly-shortleaf rapidly developed into relatively even-aged stands it became evident that the hardwood brush component would be a major problem in future operations. The need for dealing with hardwood brush was even more urgent on the areas understocked with pine. Observation of the hardwood control in repeatedly burned longleaf forests and the fact that virgin loblolly-shortleaf stands, prior to adequate fire prevention, were relatively brush free encouraged foresters to investigate the possibilities of using controlled fire in the loblolly-shortleaf type.

Investigative work to see if fire could be used successfully in loblolly pine stands mainly for brush control and seed bed preparation began in the latter half of the forties, although its use had been recommended by a few foresters for some time.

The Southeast Forest Experiment Station, several industrial forests, and later the Texas Forest Service and the Southern Forest Experiment Station established a number of test plots. By the early fifties some companies were control burning rather extensively and as the Forest Experiment Stations began to lend support and through much of the work of the Texas Forest Service, state and federal land managers began to use the tool.

The relative hazards of using fire, incorporating a program using fire into the overall public relations program, uncertainty as to the site effects, and unwillingness to cope with some of the administrative problems in a burning program have had an effect on the overall acceptance by loblolly-shortleaf pine managers.

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Paper presented at the Conference on Prescribed Fire and Smoke Management in the South. Atlanta GA Sept.12-14,1984

The prescribed burning program reported on herein has been accomplished over the last thirty-five to forty years on the lands of Georgia-Pacific Corporation, Mid-Continent Division (formerly owned by The Crossett Company) in southeast Arkansas.

Fairly extensive prescribed burns were employed on lands of The Crossett Company starting in the late 1940's. These were done both for the purpose of seed bed preparation for natural seeding and for brush control, but they were administered without much thought to how they would tie into future operations. Much of the earlier burning was done in areas that looked likely for good results. In the early 1950's some test plots were established in order to have some basis for predicting the hardwood control that could be expected under local conditions. This coincided with the time that herbicides were coming into their own, applied as basal sprays, foilage sprays or directly into the stem, first in frills and then by injector. Also, the inclination for burning the woods was diminished by the severe drought and severe fire hazard years of 1952 to 1954.

For loblolly pine managers using natural reproduction as all or part of their regeneration plan, the need for prompt and adequate reproduction under conditions where the earliest returns can be realized, accomplished by the most cost efficient means, still places the use of prescribed fire in a high priority.

The objectives of the use of fire in the loblolly-shortleaf type of the South should be broken into three major categories and more than one objective may be achieved by any one fire. They are as follows:

Fuel or hazard reduction burns.-- This can be described as the burning of fuels (generally in the form of heavy litter) under controlled conditions when there will be negligible damage, to prevent the severe damage that might occur from wildfire. Such burns are normally applied in younger stands in areas of high frequency of wildfire.

Site preparation or reproduction burns.-- These are applied where the objective is to create conditions more favorable to the establishment of new reproduction. The need is to expose mineral soil and also to kill or weaken as much hardwood as possible. Frequently this may be an area of poor to no pine stocking before or after logging, where the fuels are sparse and only adaptable to winter burning.

Brush control burns.-- The objective here is primarily to keep the brush at a size where it can be controlled with fire; the longer range objective is to reduce the quantity of understory hardwood to the point where it will be a minimum problem at the time of regeneration. Beneficial secondary effects are in the nature of better operating conditions in the stand prior to regeneration.

Georgia-Pacific's Mid-Continent Division forestry department considers the above objectives very important in its forest management work on company controlled lands in Arkansas, Louisiana and Mississippi and high priority is given to accomplish a large annual burning program. Nearly all the major forest industries in our company's operating area do some prescribed burning, although much of the recorded area consists of broadcost burns or windrow burning on site prepared lands to be planted.

Our company foresters average burning forty to fifty thousand acres per year over three states. In Arkansas, which contains nearly 60% of the Division's fee land base, it is estimated that our foresters burn one quarter of the timbered area burned in the state, excluding site prepared landburning.

All phases of our company's prescribed burning program is done with company personnel. Even though there are years when the acreage goals are not met because of weather problems or the press of other work, we do not contract out the burning as we do with other silvicultural programs.

The operational forester needs to have the goal uppermost in priority during the limited burning season to take advantage of every opportunity in order to get the job accomplished. A large scale burning program requires careful planning and coordination with other silvicultural work and with logging operations.

Planning the prescribed burn starts with reconnaissance of the forest by the forester in charge of field work on a portion of company land. Each year the forester "recon" cruises the next year's working compartment to determine cultural and cutting needs. Forest stand conditions are mapped and the coded recommended needs are overlaid on the stand map. Priority ranking of areas to be burned must be established.

Prescribed burns to establish new pine reproduction are ranked highest in priority because timing with cutting operations, season of the year, and seed crops are all critical to a successful regeneration effort.

Brush control and hazard reduction burns also require coordination in timing with other operations but not to the degree of reproduction burning. These burns are usually done on a cyclic or repeat basis on the order of three to five years. Most brush control burning is done in the winter and early spring, following the pattern of longleaf managers, burning at a time when the grass component has cured and fire carries well and potential damage to overstory pine is at a minimum. Single winter fires are not effective in killing brush so that some repetitive pattern must be maintained. Ideally, a first time winter or spring burn followed by several summer burns at two to three year intervals accomplishes the maximum hardwood control in fully stocked pulpwood and young sawlog stands but there is considerable difficulty in maintaining this schedule on an extensive basis.

The winter or spring burning season under our local southeast Arkansas conditions is from mid-October to early April. In the average year we are fortunate to have forty to fifty good burning days and the bulk of the work is normally accomplished in February and March. The summer burning season starts in June and may be considered effective through September. The percentage of days with good burning conditions is even poorer in summer, averaging twenty-five to thirty. Unfortunately, the periods of time ideal for carrying on prescribed burning coincides with the danger of wildfire occurrence and may often have an effect on number of acres burned. Company burning operations are reduced when wildfire hazard becomes severe in the fall or spring.

The silvicultural benefits of an extensive prescribed burning program in the loblolly-shortleaf forests of the mid-south are many. Any curtailment of the practice would have a great impact on forest management on Georgia-Pacific land.

Thirty-five years of experience and studies have led us to the following conclusions:

1. Prescribed burning is the most cost-effective cultural means available for controlling hardwood brush on pine land.

2. Well-stocked pulpwood or sawlog stands cast enough fuel each year for annual or biennial burns.

3. Three or four biennial summer burns can reduce hardwood sprout clumps by as much as 75%.

4. Sumner burning is not hazardous to pine overstories provided there has not been recent cutting and that there is enough wind to dissipate the heat.

5. Initial reduction of accumulated litter is essential preceeding summer burning and should be accomplished'by a winter burn.

6. Excellent pine seed bed conditions are a result of burning.

7. Fire protection from major diastrous wildfires is aided by a patchwork of control burns.

8. Working conditions for timber operations such as timber marking and logging are enhanced by burning on a regular schedule.

The techniques used in firing prescribed burns varies greatly with objective, fuel conditions, weather, and location of burn site. Each of the company operating units or districts, averaging about 50,000 acres in size, maintains a crawler tractor, fire plow, truck and trailer, six to eight man crew and two-way radio equipment. Along with the many other responsibilities of forest management and raw material supply, they prescribe burn some three thousand to five thousand acres annually.

All firing techniques are used except for aerial ignition which we have not employed yet on company lands. In general, head fires are most commonly used in reproduction burning because of lighter fuels and backing fires are used in hazard reduction and brush control burning. Occasionally flank and strip firing is done and rarely the spot firing technique. At the completion of every burn the fire line is thoroughly checked by the crew and may be checked several times for assurance that there is not danger of breakover.

Every effort is made in the company burning program to achieve the objective of the burn with a minimum of overstory pine scorch. This is a difficult goal to meet when burning a large acreage over a wide range of conditions. It is especially difficult to coordinate the timing of the burn when there is a minimum of logging debris that would cause blow ups within the burn. The cutting cycle on the majority of area burned is five to seven years so timing is critical. Heavy crown scorch has a serious impact on growth and should not be tolerated in any situation where a residual stand is to be left for growth.

Smoke management is a phase of the prescribed burning program that cannot be ignored. It is not only good public relations but also essential to the safety of employees as well as the public in a number of situations. There are few places left in the south today where forested tracts are so isolated that no one is affected by the smoke from burns. In a number of areas there has been a considerable extension of residences into rural areas and road improvement and building has made the forest more accessible to the public.

All of our company foresters have attended the cooperative USFS-State training sessions on prescribed burning and smoke management and are familiar with the guidelines to reduce the impact of smoke listed in the USFS publication "A Guide for Prescribed Fire in Southern Forests". All of the listed quidelines are good common-sense factors that Georgia-Pacific management endorses and requests its operating foresters to take into account in their burning program. Although no formal written plan is drawn up for each fire, the forester is accountable to follow the following procedure:

1. Every prescribed burn has a clearly defensible silvicultural and economic objective.

2. Weather forecasts are obtained from several local sources.

3. Checks are made with the state fire control agency to determine conditions prior to ignition.

4. Consideration is given to postponing burns in areas when conditions are not right for rapid smoke dispersion.

5. Determination of smoke drift and possible impact on sensitive areas is made prior to ignition.

6. The state fire control agency is notified of burning intent.

7. Test fires are often used to test conditions and behavior patterns.

a. Backfires are more commonly used to give more complete comsumption of fuel.

9. Relatively small blocks, ranging from forty to two-hundred acres in size are burned.

10. Burn-out and mop-up is carried on as soon as possible.

11. Nearly all burning is carried out in the daytime when burning conditions are better.

12. Crews are left to patrol and maintain fire lines until the fires are safe.

There are definite risks associated with a large scale burning program. Prescribed fires can get out of control, break over and cause extensive property damage. Variable conditions within large burn areas can cause pockets of severe damage to valuable timber. Heavy crown scorch caused by burning under the wrong conditions can retard growth. Unanticipated smoke problems can cause disagreeable or unsafe situations for neighboring landowners and the public and result in unfavorable public relations.

Over the past twenty years nearly four hundred thousand acres of Crossett Forest lands in south Arkansas and north Louisiana have been burned by company foresters. During this time there has been a high degree of success in achieving the objectives of the program with a minimum of problems.

Training, careful planning and good judgement will eliminate many mistakes and help avoid the pitfalls. Taking these factors into account, the benefits of prescribed burning in loblolly-shortleaf forests are substantial.

PRESCRIBED FIRE AND CONSULTING FORESTERS.IN THE SOUTH

L. Keville Larson, ACF[1/]

Abstract.--Consulting foresters are described as a growing force representing the best potential for expanded use of prescribed fire on private nonindustrial forestlands. Recognition by consultants and others of the true costs of prescribed burning is advocated as well as State policies to encourage the private sector, training and education in fire and smoke management and consideration of certification for prescribed burners.

INTRODUCTION

Fire is a tool of proven value in forest management and its use can contribute to increased benefits from southern timberlands. Approximately 75% of these lands are private nonindustrial forestlands (PNIF). Consulting foresters are a major source of forest management advice for PNIF and can play an important role in expanding prescribed burning activities. Consideration should be given to factors which will encourage responsible use of fire by consultants.

DESCRIPTION OF CONSULTANTS

There is no typical profile for consulting foresters. They are all independent businessmen, but the size and description of their practices vary. Seventy percent are sole proprietorships, but there are some large diversified firms employing as many as 20-30 foresters (Field, 1984). Consultants are a growing force. Their number in the South has increased from 375 in 1969 to 609 in 1980 (Pleasonton, 1969; Field, 1984). The Association of Consulting Foresters National membership has doubled every ten years since 1958. There is little doubt they will play an increasingly important role in management of the South's forests. One recent study indicated that 50% of the private nonindustrial forest owners who regenerated their lands after harvesting and 50% of those with management plans obtained their advice from consultants (Fesco, 1982). A current survey of consultants in Georgia is expected to show more than one million acres of timberland are managed by consultants in the State (Cubbage and Hodges, 1984).

Few figures are available to measure the use of prescribed fire by consultants. Field (1984) indicated that in the southeast 2.2% of consultants' 1980 gross income came from prescribed burning. Preliminary results from the Cubbage and Hodges (1984) Survey of Consultants indicates that over 100,000 acres are burned annually for TSI or natural regeneration in Georgia and another 25,000 acres are burned for site preparation. This number is put into perspective by the total estimate of 665,000 acres prescribed burned in Georgia.

Consultants adopted prescribed burning because its economy and multiple benefits help meet the objectives of clients. It was recognized as difficult, but seen as a necessary evil rather than a money making service. Many consul-

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tants only use fire on continuous management clients and do not provide it to others. The purposes are usually hardwood control, fuel reduction, wildlife habitat, and seed bed preparation. Other benefits can be reduced site preparation costs, unsolicited natural regeneration, improved timber sales, better accessibility for recreation and management. It is seldom described by consultants as a profitable service.

PROBLEMS

The most significant problems and factors limiting the amount of burning done by consulting foresters are: (1) competition from subsidized rates (2) equipment and manpower (3) risk and liability (4) weather and time.

The activities of State forestry agencies vary from State to State. Most States provide fire line plowing for a fee and some also offer burning. It is generally acknowledged the rates charged for these services are low. Similar services are also often available through industry assistance programs at cost or at a rate reflecting experience in burning large, well managed industrial tracts. In these cases the equipment and personnel costs are often charged primarily to protection or other purposes. The calculation for the independent consulting forestry business is completely different. It generally must include proper allocation of the costs of owning equipment. A dollar value or rating factor should also be attached to the substantial risk of liability which has the potential of destroying a sole proprietor's business and personal assets. There is also a cost to putting one kind of work ahead of all others on a priority schedule and the necessity of working nights and weekends. An experience and judgement cost factor may or may not be appropriate. There is a cost to exercising responsibility to the public and the environment by not taking chances with stagnation index, considering smoke management and being prepared to warn traffic or stop burning if necessary. Competition from unrealistic prices is a serious deterrent to the use of prescribed fire by consultants, because it removes the reward which motivates them.

Related to this is the problem of lack of equipment and skilled manpower. Few consultants have a truck and tractor unit. The reason frequently is because services are readily available from the State and consultants can not afford to own a unit and compete with the low State rate. The same applies to the actual burning in states which offer this service, giving consultants little incentive to train additional personnel. Usually the State or a contractor is depended on to plow lines or push out permanent 12 - 15 foot firebreaks around the tracts, and sometimes to do the actual burning. Some consultants do their own burning often with no unit standing by. They are concerned about not following the strict equipment and manpower guidelines in Forest Service and other publications, but say it is not practical or affordable at "going rates".

Liability insurance coverage is of major importance because the risks are great. Damages from a fire too hot or from an escape can be substantial, but are minor compared to the potential for loss of life and financial disaster as a result of a traffic death from smoke on a highway. Traffic accidents associated with smoke from forestry burning have increased and there is a serious need for training, education and perhaps licensing of all individuals involved in prescribed burning.

Weather and time limitations will always be a problem in expanding the amount of prescribed burning. In my opinion better understanding of weather, improved forecasts and the opportunity to make a profit will encourage consultants to make optimum use of available weather and time.

RECOMMENDATIONS

There has been considerable emphasis in forestry literature on the benefits from prescribed burning, but little attention given to the true costs. A thorough cost benefit analysis by a business oriented accountant could allow recognition by the forestry community of realistic burning costs. The prospect of a fair profit would stimulate prescribed burning on PNIF.

In most States the expressed objective is to encourage delivery of forest management services through the private enterprise sector. Enforcement of policies designed to achieve this objective is important. Such policies include not providing services where consultants or contractors are available, limitation of services to only small ownerships and setting rates which are not unrealistic. Providing information and education concerning techniques or improved weather forecasts through demonstrations or training sessions is also appropriate. In addition, careful balancing to avoid excessive regulation, but provide control through permits can encourage rather than restrict responsible private sector burning.

Consideration should also be given to licensing or certification of prescribed burners similar to that required for herbicide applicators. Currently there are no restrictions on who can carry out prescribed burning. Foresters, landowners, contractors and farmers are all involved. Foresters generally have received education and training, others may have none. Inexperienced or irresponsible people may cause serious problems. On marginal burning days it may endanger the public to give a permit to anyone who requests. Certification could provide a basis for selective permitting, which in turn would increase flexibility of those certified and reduce danger to the public and reduce potential liability of the State.

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Prescribed Fire Use by Federal Agencies in the South

DICK A. COX 1/

History does not record the beginning of the use of prescribed fire in the South by Federal agencies other than General Sherman's march through the South.

The use of prescribed fire as a management tool was recognized by the USDA-Forest Service in 1943 for the longleaf pine (Pinus palustris) and slash pine (Pinus elliotti) types only. No burning was to be done "except that which follows a systematically prearranged plan for the accomplishment of defined purpose ...". 2/ With this authority came a caution that all other agencies would be watching to see how well we carried out this charge.

Table 1 provides an historical account of the use of prescribed fire on National Forest System lands from 1943. The current burning program is approximately 500,000 acres and an ideal program would be approximately 700,000 acres.

Without specific knowledge, we assume the other Federal agencies followed the Forest Service in developing a prescribed burning program.

Taking into account the variety of Federal Land Managers--including The Department of the Army, Department of the Air Force, Bureau of Indian Affairs, Fish and Wildlife Service, Forest Service, and National Park Service--prescribed fire is truly accomplished for multiple use purposes. The most unusual is the use of prescribed fire to make targets visible for strafing with aircraft. This may not be land management but it is a use nonetheless.

Federal agencies in the South burn 786,000 to 864,000 acres annually. The breakdown is as follows (Table 2):

TABLE 2 - Annual Acreage Burned by Federal Agencies.

AGENCY	TOTAL ACRES
-Fish & Wildlife Service	62,000
-Bureau of Indian Affairs	4,000
-Department of the Army	130,000
-Department of the Air Force	68,000
-Forest Service	500,000
-National Park Service	100,000
GRAND TOTAL	864,000

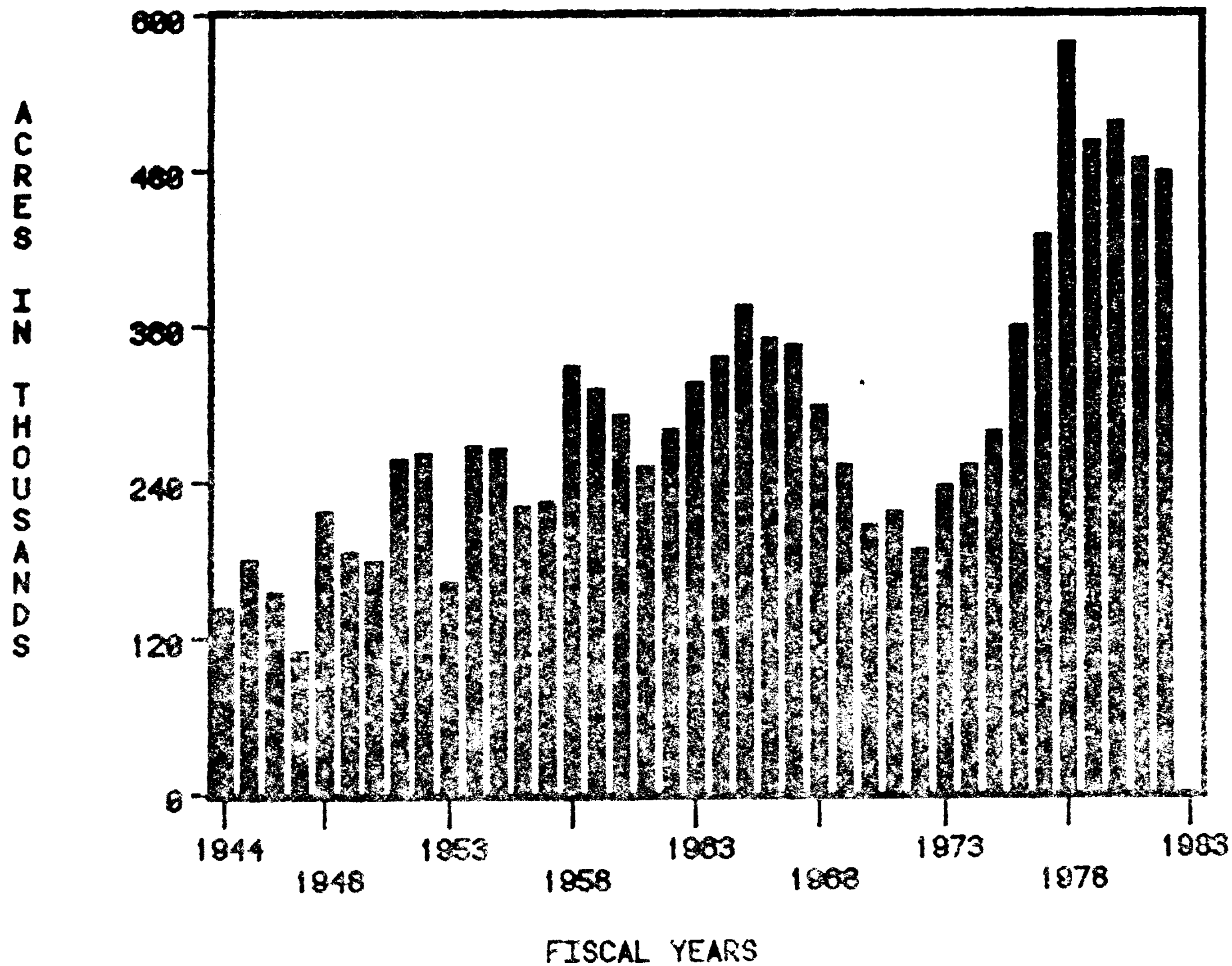
1/ Director of Aviation & Fire, Southern Region, USDA Forest Service.

2/ Letter to Regional Forester, Region 8, from Lyle F. Watts, Chief of the Forest Service, 1943.

Paper presented at the Conference on Prescribed Fire and Smoke Management in the South. Atlanta GA. Sep-t. 12-14,1984.

TABLE 1

USDA-FOREST SERVICE R-8 PRESCRIBED BURNING ACCOMPLISHMENT



A survey of agencies listed here revealed that considerable burning is conducted without a specific written plan.

The Fish & Wildlife Service, the National Park Service, and the Forest Service require written, rather detailed plans. Others require only that proper coordination takes place, burning is based on experience, or they provide only a simple written record.

The same situations apply to smoke management plans. However, all agencies expressed concern about the management of smoke and all have restricted burning in some areas because of smoke limitations. This has in turn limited their use of precribed fire.

Several of the agencies have had claims for damages resulting from prescribed fire or smoke. These range from only a few dollars through several hundred thousand for highway accidents, to a $3 million claim settled out of court.

Apparently, only the Forest Service has a training and qualification program structured specifically for prescribed fire and smoke management personnel.

Most of the other Federal agencies require experience from on-the-job training under an experienced burner.

Only the National Park Service is burning as many acres as desirable with no major problems. All other agencies are limited in accomplishing the desired acres due to various constraints. Some limitations are lack of funds, lack of adequate numbers of personnel, lack of trained personnel because of the many restrictions such as smoke regulations, and the necessity of coordination with other administrative needs and activities.

In summary, most Federal agencies have a need for a training and qualification system to enable them to accomplish more acres while meeting the requirements of new regulations, such as smoke restrictions. Aerial ignition is used by some agencies while other agency policies restrict the use of this versatile tool.

The scientific application of fire has proven to be a worthwhile, cost effective land management tool. Our challenge is to develop ways to accomplish this in the face of expanding regulations, tighter controls and reduced numbers of personnel.

SMOKE MANAGEMENT

Hugh E. Mobley[1/]

INTRODUCTION

In the past few years there has been a big change in the smoke problem from prescribed burning and the resulting restrictions, and these restrictions vary greatly in extent and format. At the time of a survey of the southern states about 10 years ago, a large majority of the states had no restrictions of any form and the few that existed were not stringent or they were in states where prescribed burning is not used extensively. Today, only three states have no regulations or any type of restrictions on prescribed burning, and one of these is now considering some type of restriction. Three states have a voluntary system that is fairly extensive. The rest of the states in the south now have some type of regulations. In most cases, these regulations are not enforced until complaints are made.

Ten years ago there was no known smoke problem in the south from prescribed burning except isolated pockets, or at least we were not aware of them. Today, the smoke problem from prescribed burning varies from being a major problem in some states to no problem in other states. Regulations have helped in some areas while in others the problem remains due to increasing population in rural areas and increasing awareness of air pollution and its effect.

Another observation I would like to make is about the concept of smoke management by forestry agencies and industry. Without exception, all groups generally comply with all regulations and restrictions including the voluntary systems. In many cases where there are no or only slight restrictions, they do more. Training, however, ranges from very little to barely adequate in most government agencies and little to none with industry personnel.

HIGHLIGHTS OF REGULATIONS

To show the general types of state regulations and how they vary, let's look at some of the state air quality regulations that apply to forestry burning.

Oklahoma

1. Prevailing winds must be away from any city or town.
2. Location of burn must not be adjacent (500 feet upwind) to an occupied residence other than those located on the property.
3. Initial burning may begin only three hours after sunrise to three hours before sunset.
4. Burning must not create a traffic hazard.

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Paper presented at the Conference on Prescribed Fire and Smoke Management in the South. Atlanta GA. Sept. 12-14, 1984.

Texas

1. There has to be no practical alternative to burning.
2. The Texas Forest Service must be notified.
3. Wind direction is such as to carry smoke away from any city, industrial area, landing strip, etc. which may be affected by smoke.
4. Burning must be at least 300 feet from any residential, recreational or commercial area.
5. Predicted wind speed must be between 6 m.p.h. and 23 m.p.h.
6. Agricultural burning and land clearing is restricted to between 9:00 a.m. and 5:00 p.m.

Florida

These regulations apply to open burning for agricultural, silvicultural or wildlife management purposes.

1. Burning is allowed only between the hours of 9:00 a.m. and one hour before sunset.
2. Authorization has to be first-secured from the Division of Forestry.
3. The division may allow open burning at other times when there is reasonable assurance that atmospheric conditions will allow good dispersion of smoke.

Mississippi

Mississippi has a different approach to the smoke problem. It is based on a stagnation index calculated by the weather service. There are four catagories ranging from: no restrictions, slight restrictions, stringent restrictions and no burning.

Voluntary Systems

North Carolina, South Carolina and Virginia have voluntary systems. They have good cooperation from industry and government agencies but little cooperation from landowners including agriculture. These systems are based on amount of fuel to be burned (based on an average fuel loading by fuel type), distance from SSA, and type of dispersion expected. Virginia uses size of area instead of an estimation of the amount of fuel. In addition, North Carolina requires a burning permit. In seventeen coastal counties, regulations on burning debris from land clearings also apply. These restrictions are based on certain hours during day, no stagnant atmospheric conditions, the amount of soil to be minimized and distance from dwellings.

States with no restrictions due to smoke

At the present, Louisiana, Alabama and Georgia have no restrictions on prescribed burning due to smoke. Louisiana has air quality regulations that don't really restrict prescribed burning. Georgia has local restrictions in counties of high population. Alabama has a growing smoke problem. We are attempting to deal with it through training and assisting industry in developing a more professional prescribed burning program that includes smoke management. A stagnation index is included in the weather forecast and this information is passed along to people requesting permits.

SMOKE MANAGEMENT

Most federal and state agencies are now practicing smoke management,. Written prescriptions are used that include some form of smoke management. Generally, the screening system described in the "A Guide for Prescribed Fire in Southern Forests" is used or one developed by the state.

Prescribed burning is part of the management system of most industries and it is used extensively in the Coastal and Piedmont areas where it is needed. The use of prescribed burning has been on more of a routine bases. Some use written prescriptions but in most cases it is left up to the discretion of the local district forester. In some cases, he is given an acreage quota and is expected to meet this quota regardless of the weather which adds to the problem. Training, however, is lacking. Lack of opportunities for training is possibly the major reason. Generally, the local people learn from working with more experienced people. Consequently, these people are hampered in being able *to* apply this experience in prescribed burning to other areas and fuel types and to be able to make better use of marginal days. In many cases; forest industries and forestland owners are not aware of a possible smoke problem until it happens and they have a lawsuit on their hands.

PRESENT SMOKE PROBLEM

I would like to summarize by highlighting the smoke problem by states:

Texas.--Smoke is a major problem in the forest areas. Debris burning and burning at night are the major causes.

South Carolina.--The voluntary system is improving the smoke problem in South Carolina but there is no cooperation from private landowners, agriculture and hunting clubs. There are several suits each year.

Florida.--Smoke problem is increasing and Florida is considering some type of additional constraints.

Alabama.--There are numerous problems and complaints each year and they appear to be increasing. We have placed a restriction on our own people burning when predicted smoke dispersion is very poor and we now use a screening system when making the prescription.

Virginia.--There is not a large amount of prescribed burning in Virginia and most of it is done by forest industry or the state. There are still minor problems and complaints because of the population.

Oklahoma and Arkansas.--Both states have regulations and the amount of burning is small, Consequently, smoke is not a problem.

North Carolina.--With the regulations in the coastal counties and an aggressive voluntary system in the rest of the state, the smoke problem in North Carolina has been drastically reduced. Their major problem is inadequate lead time with weather forecasts.

Georgia and Louisiana.--Forest land is in more rural areas and employment in local communities is mostly forestry oriented. Consequently, there is no major smoke problem from prescribed burning at the present.

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WEATHER, FIRE DANGER RATING SYSTEMS AND FIRE BEHAVIOR USE IN PRESCRIBED BURNING AND SMOKE MANAGEMENT IN THE SOUTH

John G. Shepherd[1/]

Abstract.--State-of-the-art applications of weather, fire danger rating, and fire behavior in smoke management and prescribed burning by southern fire managers are addressed. Validations of fire predictive systems versus observed fire conditions are stressed as a prime need in the south.

Keywords: Prescribed fire, smoke management, fire danger rating, weather, fire behavior.

MY topic for this session on Prescribed Fire and Smoke Management in the South deals with the state of the art applications in weather and fire danger rating. One additional area that is an integral part of weather application is the basic utilization of fire behavior.'

Williams (1977) aptly stated that fire is used: 1) to consume organic matter and undergrowth (fuel) that poses a potential wildfire hazard and hinders management, harvesting, and other uses of the forest, 2) to prepare forest sites for reforestation 3) to control competition and maintain a desirable balance of tree species and other vegetation 4) to minimize adverse effects of insects and diseases, and 5) to create conditions favorable for wildlife or livestock.

Hugh Mobley has discussed the current smoke management regulations or guidelines that are in use by the Southern States. The combination of the prescribed burn requirements combined with our responsibility to properly manage smoke provides a never-ending challenge to the fire manager.

WEATHER

The basic weather components of temperature, wind, and relative humidity have been used for decades. In 1981, Jim Paul with the Macon Fire Lab conducted a survey which, in part, addressed the question of what weather parameters are currently in use for fire management in the South. Over 60% of the responding states reported using the following weather related information in their fire management activities: temperature, relative humidity, wind speed & direction, mixing height & transport wind speeds, cloud cover, maximum & minimum temperatures & humidities, and precipitation amount and duration. As our expertise continues to develop with technological advances, with field applications, and with field validations, we find that we must be more finite in the combinations of these basic weather parameters to meet fire and smoke management needs.

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Paper presented at the Conference on Prescribed Fire and Smoke Management in the South. Atlanta GA. Sept. 12-14, 1984.

Two studies (Sackett 1975 & Mobley 1977) determined that high wind speed is needed for backing fires and low to moderate winds for head fires to disperse heat and prevent mortality in pine overstory. Persistent wind is a prime consideration within a stand as it is being burned to prevent flare-ups. In the South, persistent winds are associated with a cold front with prevailing winds from the west to northwest following the cold front passage.

The temperature and relative humidity relationship is currently utilized to provide fine fuel moisture estimations. A southern fire manager now seeks a 6% to 10% fine fuel moisture range when considering burning for hazard reduction. Over 80% of hazard reduction burns are accomplished during the fall and winter months with these weather guidelines: Temperature 20 to 50 degrees Fahrenheit, humidity 30%-50%, wind speed 2-5 mph in the stand, and burning accomplished after a significant rain (usually 1 day after precipitation in longleaf stands and 2-3 days after precipitation in loblolly stands.)

The most recent expansion of weather needs in the South has been evaluation of the upper atmosphere wind field and development of procedures to forecast certain parameters in the upper atmosphere. Most of the Southern States have what is referred to as smoke dispersion categories, smoke dispersion indexes, or stagnation indexes. Basically, these are ventilation rates that combine mixing height and transport wind speeds in the upper atmosphere. Most systems in use identify this in a gradient format ranging from little or no smoke dispersion capability to extremely high smoke dispersion capability. The fire manager now realizes that in order to insure good smoke dispersion that inversions must be burned off and given surface temperatures must be reached before such inversions are terminated. On the other end of the scale, extremely good smoke dispersion capability can result in interaction with a burning operation to create a blow-up fire situation.

The Southern Forestry Smoke Management Guidebook (1976) provides the methodology for in-depth applications on prescribe burning and smoke tracking procedures to help prevent adverse impacts of smoke on target areas.

What are some challenges in the general realm of weather?

Cooper (1971) stated in 1971 that over 10 million acres in the South should be burned each year and that contrary to what many of us think, the days to burn <u>are</u> available. The problem identified is that fire managers are not aware of these days and/or cannot take advantage of the favorable burn days to implement burning operations.

Our weather forecasts have been tailored to provide the specific weather data we request, but as the need to burn more acres on fewer days increases, the accuracy of the 2-3 day outlooks must be improved. More basic information is needed to provide forecasting accuracy for ventiliation rates for day and night time frames. However, weather forecasters must not work in a vacuum. Field weather observations must not only be taken by user agencies, but these data must be provided to weather forecasters for verification of forecasts. Several southern states are requiring that field weather observations must be transmitted to weather forecasters prior to spot forecasts issuance to the requesting user.

It's a two-way street!

FIRE DANGER RATING

A tool that is in use in the South to assist in planning for prescribed burning and smoke management is fire danger rating. Basically, the 1964 and 1978 fire danger rating systems have been implemented in the Southern States for long range planning purposes. One index that is commonly used, but with different applications, is the build-up index from the 1964 fire danger rating system. Most of the Southern States maintain build-up index information to measure cumulative drying of heavy forest fuel beds. Ranges of cumulative drying have been used to alert forest agencies and cooperators to potentially severe burning conditions and prescribed burning operations have been terminated when build-up indexes reach extremely high ranges. Florida uses an adjective fire hazard rating using the build-up index: o-15 Low, 16-40 Moderate, 41-80 High, 81-200 Very High, and 200+ Extreme. In North Carolina, a build-up of <25 provides an indication that peat fuels will ignite and smolder. Another application of the build-up index is its combination with 20-foot standard wind speed and mixing height to approximate convection column height which has application in smoke management programs.

The 1978 National Fire Danger Rating System (1978) is designed to provide fire danger indexes and components for a relatively large geographic area. The 1978 NFDRS is not applicable as a fire behavior tool for individual fire(s). The burning index, which uses the spread component and energy release componment, is being applied in fire planning efforts for prescribed burns in relatively large geographic areas. The measured lo-hour time lag fuels (1/2" fuel moisture sticks) are used to determine when ignition can take place in slightly shaded hardwood and pine litter fuels. Field tests have indicated that at a moisture content of 15% or less, these litter fuels will ignite and burn.

One major problem that field personnel have identified in the 1978 NFDRS is in one of the brush fuel models basic structure. This model indicates a very rapid rise in indexes and components following a significant precipitation event. This brush fuel in the South normally has a heavy litter layer under the brush strata and initial ignition is in the litter layer. Shading by the brush strata restricts rapid drying and resulting fuel moisture in the litter is much higher than indicated by the 1978 NFDRS.

FIRE BEHAVIOR

The fire behavior side of prescribed burning can best be thought of as a small pane of glass in the bigger window of fire danger rating.

Southern fire managers are continuing to refine the use of weather in fire behavior estimations. Currently, weather inputs are combined with related fuels and topography to determine forward rates of fire spread, flame length, and ignition component for prescribed burn operations. This information is derived using Rothermel's (1983) equations, nomograms, or the T.I. 59 handheld calculator. The procedure, designed primarily for wildfire predictions by fire behavior specialists is being applied to the prescribe burning field. Although, Anderson's "Aids to Determining Fuel Models for Estimating Fire Behavior" (1983) is an excellent source document for identifying fire behavior fuel models, the primary problem is the existing fuel models in the fire behavior system do not always match fuels in the South.

This situation is being addressed in an improved version of the fire behavior sys tern "BEHAVE : Fire Behavior and Fuel Modelling System" (1984) recently completed at the Northern Forest Fire Laboratory in Missoula, Montana. This system, in part, enables the user to build customized fuel models that can be used in the T.I. 59 or through a larger computer system to more accurately approximate on-site fuel conditions. Further customizing a fuel model can lead toward the goal of matching observed fire behavior with predicted (forecasted) fire behavior.

OBSERVATIONS

There is a continuing need to promote weather data exchanges between weather forecasters and prescribe burners. The transmission of on-site weather data provides the weather forecaster with raw data which assists in constructing weather forecasts for the specific site and can provide verification for a weather forecasters' products. Although the majority of on-site weather observations are taken with a simple belt weather kit, the technology is available through devices such as the portable RAWS to continuously record and transmit on-site weather data to off-site meteorologists or other users.

The limited number of upper atmospheric soundings in the Southern States cannot adequately provide background data for day and night smoke dispersion forecasts. Although military and local agencies supplement this data with pibal readings, the increasing demands on smoke management will require continuing procedural refinements and long-range forecast accuracy.

Fire danger ratings systems are in use in most Southern States. The primary reason for operating under any particular system is the reliability factor of the indexes or components most commonly used. In North Carolina our original intent was to use and apply all the indexes and components in the 1978 NFDRS . At this point in time, we are stressing the use of the burning index, ignition component, and spread component. We also use the build-up index from the 1964 NFDRS. The energy release component (1978 NFDRS) could possibly replace the 1964 build-up if it is easily understood, and provides more useful data in addition to the cumulative drying of heavy forest fuels. Fuel models in the fire danger rating systems need review/revision with the prime emphasis aimed at field verification.

Fire behavior as applied to prescribed burns has made significant strides in recent years. Here also is a need for field verification under carefully measured weather conditions.

COMMENTS

It is apparent that in order to accomplish the goals in prescribed burning that we must be aware and take advantage of what we commonly call "burning days" or "burning windows." With innovations such as aerial ignition, the concept of forced ignition begins to take shape. Aerial ignition tests in North Carolina have shown that grid spacing of ignition devices is critical in energy release consideration in prescribed burning. Initially, the grid spacing of 1/2 chain x 1/2 chain was thought to be optimum for hazard reduction burning. In moderate to heavy fuels, this spacing resulted in heavy overstory scorching due to the amount of energy released in a very short period of time. Wider spacing of aerial ignition devices can provide lesser energy release levels with good fuel reduction results. If we cannot find the exact conditions to meet the prescription that we have defined on a particular burn, our firing methods can be modified to create the type of burn that will meet our prescriptions. If we can't modify the weather, modify the method of firing.

A Priority Burning System similar to the one implemented in Oregon may provide answers to smoke management problems. Hopefully, this type of system could be put into place through the Voluntary Smoke Management Guidelines that many southern states use.

Training is being implemented in many southern states, addressing all areas of prescribed burning. A Prescribed Fire and Smoke Management Training session was held in 1981 at the Withlacoochee State Forest in Florida. The trainees were from federal, state, and forest industry agencies with representatives from western, northeast, and southern states. In-house state training sessions have been conducted, following the Florida training sessions to pass on technological and practical applications in the field of prescribed burning and smoke management. Burning bosses, defined as individuals who are qualified to develop and execute burning plans, are-trained in suppression courses through the levels of: Organizing for Fire Suppression, Sector Boss, and Intermediate Fire Behavior.

Finally, increasingly complex prescribed burning plans are reaching into forest industry communities in the South. The public concern for environmental protection requires greater documentation and planning efforts by all forest interests in prescribed burning and smoke management.

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PRESCRIBED FIRE - ITS HISTORY, USES, AND EFFECTS IN SOUTHERN FOREST ECOSYSTEMS

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Abstract.--The character of most southern forest ecosystems has been shaped by fire. Indians and early settlers fired the woods for many purposes. After a period of attempted fire exclusion, foresters recognized the necessity of fire by prescription in southern pine cover types. This paper describes the history, uses, and effects of prescribed fire in the South. When properly applied, prescribed fire has many benefits and minimum adverse environmental effects. While a substantial body of knowledge exists concerning prescribed fire, much remains to be learned to fine tune the practice.

Additional key words: wildlife habitat, water and air pollution, nutrient cycling

INTRODUCTION

Prescribed burning is a multi-faceted forest management tool with a history almost as old as southern forestry itself. Evolving from a tradition of random woodsburning by both Indians and early settlers, prescribed fire is now a mixture of science and art--a concoction whose benefits are considerable when properly applied but whose liabilities can be self-limiting if sound judgment is not used in its application. Since prescribed fire is an extremely valuable management tool, both from the standpoint of versatility and cost, it behooves us as foresters to critically evaluate its role in southern forest management and to analyze the impacts, both positive and negative, of the practice on the environment.

The current role and importance of prescribed fire in the South can best be appreciated if we look at the history of fire in the region. Man and fire have coexisted here for about 20,000 years (Komarek 1974) and the character of southern forest ecosystems has come to depend on their mutual interaction.

HISTORY OF FIRE IN THE SOUTH

Fire has always been a natural and important ecological force helping to shape most of the forests of the world (Spurr and Barnes 1980). Through geologic time before the advent of man, lightning served as a mutagenic agent which forced species and communities to adapt or perish (Komarek 1974). Evidence of ancient fires can be found in peat beds, and scars from lightning strikes have been observed on petrified trees. There is little doubt that plants and plant communities evolved under a regime of periodic lightning-induced fire prior to the advent of prehistoric man.

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With the arrival of the early Indians in the Southeast some lO,OOO-20,000 years ago, fire became a more frequent occurrence. These early Americans depended on fire to drive game and for improving habitat of the animal species they depended upon. Fire enabled these primitive people to control their environment, and early man preferred the open grassland or savannahs which resulted from frequent burning. Such environments provided man access to the grazers and browsers of the grasslands and to the wild grains, berries, and legumes that appeared after fire. Frequent (annual in many areas of the South) fires reduced the heavy growth of underbrush so that he could move safely from area to area with less fear of ambush or attack. The heavy use of low-intensity surface fires at frequent intervals, coupled with the occasional conflagration during times of drought, produced the open grassland and forests free from underbrush when the early settlers arrived. Plant communities evolved which not only tolerated fire, but which actually required it for their existence.

European settlers quickly discovered the advantages of firing the southern woods. Their livelihood was often based on hunting and herding, the success of which depended upon frequent burning. In the South, understory growth was exceptionally vigorous and.had to be controlled if grazing and hunting were to survive. Frequent low-intensity burning kept the "rough" under control, but did little to harm the pine and pine/hardwood overstory. Burning to keep the woods open became a southern tradition. Only with fire could farmers keep their grazing lands open, prepare sites for crops, eliminate or reduce pests, and dispose of crop debris (Pyne 1982). Improved grazing for their cattle, better hunting, and temporary pest eradication were obvious benefits that anyone could readily observe; and of course, dangerous wildfires were uncommon because fuel loads were light.

So woodsburning became an integral part of the agarian South. As farmlands wore out from repetitive cropping, new lands were cleared and annual fires prevented the aggressive southern pines from reclaiming the abandoned farmland. Such was the picture of the South until the 1880s--a pastoral economy maintained in large part by woodsburning.

At this time, the logging industry migrated into the South from the Lake States. After a few decades of exploitive logging, most of the virgin pine forest had been cut, and fires set to consume logging slash, as well as those to improve grazing, prevented regeneration. Professional foresters arrived in the South about the time the last virgin pine forest was being cut. Over 92 million acres of cutover timberlands faced them. It was obvious that control of random woodsburning was mandatory to allow regeneration of the forest.

The U.S. Forest Service was adamantly against the use of fire in the woods during the early decades of the 20th century (Pyne 1982). Even light-burning was prohibited on recently established National Forests in the South. Forest Service policy coupled with the establishment of state Forestry agencies to protect forests from fire sought to create an environment totally different from that of previous millenia. The coming of industrial forestry to the South in the 1930s required organized fire protection in an era when annual woodsburning was as natural as applying fertilizer to agricultural crops is today. Forestry created the necessity of fire control, or at least using fire on a different cycle, and brought forestry organizations into conflict with traditional fire practices. Of course, a long-standing tradition such as woodsburning dies slowly, so the forests burned but not as frequently as before.

Much debate ensued over the controversy concerning the role of prescribed fire in forestry. Gradually, the importance of the proper use of fire became established. H. H. Chapman of Yale University in the early 1900's had distinguished between wildfire, prescribed fire, and woodsburning and advocated the use of prescribed fire in longleaf pine management. The wildlife biologist Stoddard (1931) had published his monumental study on the importance of prescribed fire in the management of bobwhite quail. The consequences of a fire exclusion policy were brought home by a series of disasterous wildfires in the thirties and forties and especially the fifties which convinced many foresters of the potential use of prescribed fire in reducing fuel hazards and, therefore, wildfire damage. The naval stores industry, which had been active since the 1700s, had demonstrated that annual burning could protect valuable timber from wildfire by reducing fuel hazard (Pyne 1982). Today, prescribed fire is recognized as an essential forest management tool by most foresters, but the general public and certain regulating agencies have little understanding of its use and importance: Its benefits and liabilities are still being debated.

CURRENT PRESCRIBED FIRE USES

Prescribed fire, i.e., fire to accomplish specific planned management objectives, is used for many purposes. Fuel reduction is the primary use of prescribed fire, especially in the vast pineries of the Coastal Plain. Without periodic burning, a dense understory of hardwoods, vines, grasses, and pine straw develops rapidly into a highly dangerous rough. Within a period of a few years, this rough, if ignited, could produce a high-intensity fire capable of destroying the overstory and doing extensive damage to property. Komarek (1984) described how pine stands with heavy accumulations of fuels can be burned several times within one year, taking off a layer of fuel each time. Too often foresters attempt to reduce fuels too quickly.

Prescribed fire is used to control fuel accumulation in young pine plantations prior to thinning. Generally, the first burn should be a low-intensity backing fire during cool (< 50°F) weather and with sufficient steady winds to dissipate heat away from the low crowns. In slash and loblolly pine stands, the first burn can be accomplished when total height of stands averages about 15 feet, according to the USDA Forest Service Region-8 prescribed fire guide. Ground diameter should be at least 3 inches to prevent cambium scorch. Soil and lower litter should be moist and fuel loading light to prevent levels of fire intensity that could damage the stand. Suitable conditions for this type of burning normally occur 1 to 3 days after passage of a strong cold front with rain.

Long-term research has shown that the hardwood understory can be controlled with either periodic or annual burning (Lotti 1961, Harshbarger and Lewis 1976, Langdon 1981). Low intensity prescribed fires in pine stands are not effective in top-killing hardwood stems greater than 3 inches in diameter (Ferguson 1961). Summer fires tend to be more effective in killing tops than winter fires. Root stocks of hardwoods generally sprout following either winter or summer fires, although sprouting vigor is greater following winter fire. Annual winter burning will reduce the size of understory hardwood stems, but not eliminate them even if done for decades, Repeated annual summer fires will completely remove small understory hardwoods from the stand.

Prescribed fire can be used to prepare seedbeds or sites for planting. Fires used to prepare seedbeds for natural seeding are generally of low intensity since burns are normally conducted in advance of heavy cutting and the seed-producing trees must be protected. Low-intensity burns have been used effectively in the Coastal Plain (Lotti 1961) and Piedmont (Van Lear et al. 1983) to regenerate loblolly pine by clearcutting with seed-in-place. Similar types of burning are recommended prior to the reproduction cut in the seedtree method or any cut in the shelterwood method (Baker and Balmer 1983).

For site preparation prior to planting, burning intensity is higher since logging slash must be reduced. The most effective site preparation burning is generally done in the first summer following logging, although it can be done in any month. During the summer months, sprouting from burned hardwood stumps is less vigorous because stored carbohydrates in the roots are at low levels. Burning of the lush green vegetation of summer can be more readily accomplished by felling residual whips and culls after spring leaf out, followed by a month or so of curing, and burning in July or August.[2] This procedure allows site preparation burns to be done within days after soaking rains when the lower forest floor and soil are still moist, thereby keeping potential soil damage to a minimum. The number of burning days, which is often limiting, is increased because of the presence of cured fuels. In addition, adjacent uncut stands are less at risk because fine fuels in these stands are at a higher moisture content than in the clearcut area.

Wildlife habitat can be improved or degraded by prescribed fire as countless studies and several bibliographies and symposia have shown (Lyon et al. 1978, Harlow and Van Lear 1981, Wood 1981). With hundreds of species of mammals, birds, reptiles, and amphibians in southern forests, this should not be unexpected. Prescribed fire can improve habitat for many of the major game species by increasing sprouting of browse, by providing seedbeds for legumes and herbaceous vegetation, by stimulating germination of seed stored in the forest floor, and by setting back succession to create or maintain cover requirements. Knowledge of the habitat requirements of species to be featured in management, particularly those of threatened or endangered species, will allow fire to be used or prohibited to accomplish management goals. However, southern wildlife evolved under a regime of periodic fire, so it should not be surprising to discover that prescribed burning is beneficial to most wildlife species.

Prescribed fire can be used to control brownspot needle blight in longleaf pine seedlings. Seedlings of this species are sensitive to this disease as well as competition from other plants. Annual burning after seedlings are large enough to resist damage can control both factors and encourage rapid height growth out of the grass stage (Boyer and Peterson 1983). Prescribed burning may also play a role in reducing incidence of root rot. Froelich et al. (1978) reported that incidence of Annosus root rot was reduced in loblolly

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[2] Personal communication with Jim Abercrombie, Assistant District Ranger, Andrew Pickens Ranger District, Sumter National Forest, South Carolina.

and slash plantations in the Coastal Plain burned prior to and after thinning. The authors speculated that increased post-fire temperatures on burned plots or greater competition from other fungal competitors, rather than reduced inoculum, was the cause of the reduction.

Other use of prescribed fire are also important. It is used to improve forage for grazing by increasing the palatability, quality, quantity, and availability of grasses and forbs (Komarek 1974). It also removes underbrush, allowing for more efficient marking and harvesting of timber. Frequent burning creates an open, park-like appearance in stands which is esthetically pleasing. In addition, the diversity of flowering annual and biennial plants in these oft-burned stands is increased, thereby improving the appearance of the area and perhaps its ecological stability.

EFFECTS OF PRESCRIBED FIRE

Soil

Many factors, including fire intensity, ambient temperature, vegetation type, and soil moisture influence the effects of fire on the soil (Wells et al. 1979). Low-intensity prescribed fires may improve productivity of Coastal Plain soils (McKee 1982). Results of long-term prescribed burning studies in the Coastal Plain of South Carolina and Florida showed that available phosphorus, exchangeable calcium, and organic matter of soil on burned plots were higher than those on unburned plots. The finding that phosphorous availability was increased is significant because most Coastal Plain soils are phosphorus deficient. Burning apparently increases exchangeable calcium in the soil by reducing the immobilization of the element in the forest floor, thereby allowing it to leach into the soil. Increased organic matter after burning was probably the result of greater abundance of fibrous-rooted grasses and legumes, plus the accumulation of charred material in the soil profile. Total nitrogen in the mineral soil was not decreased by periodic burning and may be increased by annual winter and summer burning because of greater abundance of N-fixing legumes and more herbs on burned plots. Nitrogen in the forest floor was reduced because of volatilization and perhaps, to a minor extent, leaching. McKee suggests that periodic burning slows the weathering process and may help maintain soil productivity by reducing the leaching of cations by organic acids from the forest floor.

Prescribed burning normally removes only part of the forest floor. In Arkansas, Moehring et al. (1966) found that a decade of low-intensity annual burnings reduced the weight of the forest floor by 64 percent. Similar results have been reported for other long-term burning studies in South Carolina (Metz et al. 1961) and in Virginia (Romancier 1960). Single, low intensity burns in previously unburned Piedmont pine stands consumed about 5,000 to 6,000 lbs/ac of forest floor (Brender and Cooper 1968, Kodama and Van Lear 1980). Even high-intensity broadcast burns generally leave portions of the forest floor intact, because rarely do these types of fires burn uniformly hot over the entire area. Prescribed fire is a random process (Johnson 1984), and there are always areas that fail to burn or burn only lightly, even in generally intense fires. The quantity of forest floor left unconsumed can be controlled by the prescription and execution of the burning. Broadcast burns set when the lower forest floor and soil are moist seldom consume the entire duff layer, especially when relatively fast-moving head fires are used.

Amounts of nitrogen volatilized during low-intensity burning in loblolly pine stands have been estimated between 20 lbs/ac (Kodama and Van Lear 1980) and 100 lbs/ac (Wells 1971). Sulfur is also volatilized during burning, but amounts lost would be small because of low concentrations in forest fuels. High intensity fires used to eliminate logging slash, which averages about 20 and 30 tons/ac following harvest of upland hardwoods and bottomland hardwoods, respectively, and 9 and 3 tons/ac in natural and plantation pine (Phillips and Van Lear 1984) would volatilize much larger quantities of nitrogen, possibly in the neighborhood of 200-400 lbs/ac.

Effects of losses of this magnitude on soil nitrogen status are difficult to predict. Amounts of nitrogen in southern forest soils vary widely, but probably average about 2,000 lbs/ac (DeBell 1979), the vast majority of which is unavailable to plants. Nitrogen is continually being added to southern ecosystems. Jorgensen and Wells (1971) and Van Lear et al. (1983) measured rates of 1-4 lbs/ac/yr via non-symbiotic N-fixation in undisturbed pine stands on Piedmont sites. Jorgensen and Wells (1971) found nonsymbiotic nitrogen fixation rates were increased (from about 1 lb/ac to 23 lbs/ac/yr) by burning on poorly drained Coastal Plain soils. They suggest that burning improves those site conditions associated with a higher rate of fixation, i.e., more available nutrients, higher soil moisture and temperature. Nitrogen inputs from precipitation approximating 5 lbs/ac/yr have been measured in the Southern Appalachians (Swank and Douglass 1977) and in the upper Piedmont (Van Lear et al. 1983). Over the course of a rotation, it would appear that these inputs could balance nitrogen losses due to burning.

Rates of symbiotic nitrogen fixation by native legumes and non-legumes in the South have not been well documented over the course of a rotation. However, early stages of plant succession are often dominated by nitrogen-fixing species, especially in ecosystems with a high fire frequency (Gorham et al. 1979). Permar and Fisher (1983) found that wax myrtle, even though accounting for only 8 percent of the crown cover, fixed about 10 lbs/ac/yr nitrogen in a young pole-size slash pine plantation in Florida. Boring and Swank (1984) reported that 4-year-old stands of black locust fixed about 30 lbs/ac/yr in the Southern Appalachians. Cushwa and Reed (1966) documented a 7-fold increase in legumes on clearcut areas followed by slash burning, although nitrogen fixation rates were not measured. The abundance of annual legumes decreases rapidly as other herbaceous vegetation becomes established and the crowns begin to close.

There is little evidence to suggest that low-intensity burns have any adverse effect on soil erosion, even on relatively steep slopes. Goebel et al. (1967) and Brender and Cooper (1968) measured insignificant soil losses following single prescribed burns in the Piedmont. Douglass and Van Lear (1983) found that two low-intensity burns prior to harvest had no effect on nutrient or sediment concentrations in ephemeral streams in the Piedmont of South Carolina. Cushwa et al. (1977) also failed to detect significant soil movement in established gullies following moderately intense backfires in mature loblolly pine stands in the South Carolina Piedmont. However, Arend (1941) reported that infiltration rates of Missouri Ozark soils were reduced by 38 percent by repeated annual burning in oak-hickory stands. Increased overland flow caused by reduced infiltration could have increased erosion, but this was not documented.

High intensity site preparation burns conducted under conditions of high fuel loads and low moisture may burn completely to mineral soil, and may accelerate soil erosion in steep terrain. Such losses have not been documented in the South. The site-preparation burning program of the U.S. Forest Service on the Sumter National Forest in South Carolina, described earlier, uses summer burns in heavy fuels with little visible evidence of soil erosion. However, if the drying period is too long, fires may burn so hot that mineral soil is exposed over much of the area, and significant erosion could possibly result in steep terrain. By felling leafed-out residuals and allowing their foliage to cure, site preparation burns can be conducted soon after soaking rains--an obvious advantage as far as soil protection is concerned.

Questions remain concerning effects of prescribed fire on southern soils. However, evidence indicates that low-intensity prescribed fires have little, if any, adverse effects on soil properties and may even improve them. High intensity prescribed fires have a temporary negative effect on site nutrient status resulting from volatilization of nitrogen and sulfur, plus some cation loss due to ash convection, but this appears to be short-lived as nutrient accretion is rapid. Effects of high intensity fires on soil physical properties are not well documented, but the infrequent use of such fires (once a rotation) and the resilience of soutbern forest ecosystems to fire would suggest adverse effects on the soil are minor.

Vegetation

Since forest ecosystems have been subject to forest fire for eons, plants have had to adapt to fire or perish. Adaptations have taken many forms. Some species have thick insulating bark which protects them from the scorching heat of surface fires. The lethal temperature of protoplasm is thought to be about the same for all plants. A temperature of 147°F is instantly lethal, while somewhat lower temperatures require more time to kill plant tissues. Thus, the nature and thickness of the dead outer bark are critical in protecting the living inner bark and cambium from fire damage (Hare 1965).

Mature longleaf pine is well known for its resistance to fire damage because of its thick bark. Slash, loblolly, and shortleaf pine also generally survive bole scorch when they reach sapling size or larger (Komarek 1974). Virginia pine and white pine tend to have thinner bark and are more susceptible to fire damage. However, when pine trees are young, crown scorch, rather than cambium damage of the bole, is the principal cause of mortality (Storey and Merkel 1960, Cooper and Altobellis 1969).

Another fire adaption of southern pines is their ability to leaf out soon after defoliation. Most southern pines larger than sapling size can tolerate a high degree of crown scorch, expecially during the dormant season, with minimum effects on survival and growth (Komarek 1974). Trees are most susceptible to crown scorch during the spring when leaders are succulent. During the summer and early fall, pole-size loblolly pine can generally tolerate all but complete scorching of foliage and still recover. Lower crown classes are more susceptible to fire-induced mortality than are dominant and codominant trees (Waldrop and Van Lear 1983). Diameter growth apparently is not significantly affected when trees have the opportunity to produce new foliage prior to the start of the next growing season.

Cone serotiny is an adaptation to fire by many coniferous species throughout the country. Of the southern pines, pitch, Virginia and sand pines exhibit this characteristic of storing seed in closed cones for years until opened by fire or high heat. Natural shedding of lower branches is another feature associated with certain species which exist in fire environments. Those Southern pines which developed under a high frequency fire regime are characterized by being good pruners--an adaption that prevents the spread of surface fires into the crown.

Above-ground portions of hardwood species are not generally as resistant to fire damage as conifers, primarily because of thinner bark. Bark thickness in hardwoods is not as critical to hardwood survival because fires in Southern hardwoods normally burn in light fuels and are of low intensity (Komarek 1974). However, some hardwoods develop exceptional bark thickness upon maturity. Yellow-poplar is one of the most fire resistant species in the East when its bark thickness exceeds one-half inch (Nelson et al. 1933).

Foresters' fear of damaging stem quality has led to the general policy of excluding fire from hardwood stands. However, evidence of damage to boles of hardwoods is primarily that obtained from the study of wildfires, which burned with higher intensity than prescribed fires. These fires often burned in the spring when trees are most susceptible to damage. Because of these early reports, fire research in hardwood stands has lagged far behind that in pine. Although there is no doubt as to the serious adverse effects of high intensity wildfires on stem quality in hardwood stands, the role of low-intensity prescribed fires in stand management and the use of higher intensity broadcast burning in promoting quality coppice regeneration deserves greater attention from fire research.

Hardwoods, while generally lacking the fire resistance of pines, have developed another adaption to insure their survival in ecosystems where fire is a periodic visitor. They all sprout, generally from the base of the stem or from root suckers, when tops are killed. Supressed buds at or below ground level often survive the heat of a surface fire, and sprout in response to the loss of apical dominance. Generally many sprouts will develop from a stump, but over time they will thin down to one or a few per stump. Fire promotes good quality sprouts by forcing them to develop from the ground line or below; thus the developing stems tend to be free of rot and well-anchored (Roth and Sleeth 1939, Roth and Hepting 1942).

Many southern species have adapted to a high frequency fire regime by developing light seed, which can be wind- and gravity-disseminated over large areas. These light seeded species often pioneer on burned seedbeds. Some species, yellow-poplar for example, produce seed that remain viable for years in the duff. Yellow-poplar seed stored in the lower duff germinates rapidly following winter prescribed fires (Shearin et al. 1972).

Herbaceous vegetation thrives on fire-prepared seedbeds. Legumes were more abundant in young loblolly pine plantations in the Georgia and Virginia Piedmont on plots where logging slash was burned (Cushwa et al. 1966, Cushwa and Reed 1966). However, single, low-intensity prescribed fires in unthinned pine stands are not likely to stimulate production of herbaceous plants, because either mineral soil is not exposed or light is limiting to germination or growth.

Fire affects not only individual plant species, but also entire communities. Community structure is altered by burning, e.g., a shrub layer may be completely eliminated and replaced by a grass and forb layer if burning is frequent. The absence of fire will favor in the long-run more shade-tolerant, less fire tolerant species and succession will proceed toward a climax community, rather than a fire-maintained subclimax type (Spurr and Barnes 1980).

Periodic fires at intervals of several years favor species which are more fire-resistant than their competitors. A series of periodic fires prior to harvest of mature hardwood stands may increase the number of oaks in the advance regeneration pool (Little 1974), an important consideration in the reestablishment of stands with a large oak component. Studies in the northeast indicate that oak seedlings resist root kill by fire better than their competitors, thereby giving oak an ecological advantage (Swann 1970, Niering et al. 1970). Advance regeneration of oaks in central Tennessee was doubled by both annual (for 6 years) and periodic (at 5-year intervals) pre-harvest prescribed fires (Thor and Nichols 1974). A single low-intensity prescribed fire, however, had only a slight positive effect on increasing the relative position of oak advance regeneration in'the mountains of South Carolina and Georgia (Teuke and Van Lear 1982).

Intense fire in young mixed hardwood stands may favor oak, as noted by Keetch (1944) and Carve11 and Maxey (1969) both of whom observed that species composition of mixed hardwood stands was converted to predominately oak by wildfire. McGee (1979) did not observe this beneficial influence of fire on oak on the Cumberland Plateau in north Alabama. Burning in both spring and fall in 5-6-year-old mixed hardwood stands increased only the relative dominance of red maple. Obviously much remains to be learned about the use of fire to alter species composition in hardwood stands.

Wildlife Habitat

Just as plants and plant communities in the South have adapted to a regime of frequent fire, so have the animals which live in these communities. Effects of fire on the habitat of the white-tailed deer and bobwhite quail have received the most study. Increased sprouting of hardwoods and other browse after fire has been well-documented (Lay 1957, Harshbarger and Lewis 1976, Stransky and Harlow 1981). Burning generally increases protein, phosphorus, and calcium contents of browse, as well as enhancing its palatibility, although the duration of these effects are often short-lived. In addition, periodic winter and summer burns temporily increase numbers of woody plant stems, forbs, grasses, and legumes. Forage yields in Florida were higher after spring than fall and winter burns (Lewis 1964). Numerous workers have noted that repeated annual summer burns will destroy root stocks of most browse (woody) plants eliminating understory mast-producers and leading to site domination by fire-tolerant forbs and grasses.

Although sprouting is increased by most burning regimes, some workers have reported temporary decreases in fruit production following periodic burning. Fruit production of gallberry, huckleberry, and blueberry was reduced the first year after prescribed burning in 16 to 30-year-old slash pine plantations in Georgia, but markedly increased by the third year (Johnson and Landers 1978). In Florida Hilmon and Hughes (1965) noted that fruiting of gallberry plants was set back the first year by fire, but they bore heavily the second year. Stransky and Halls (1980) found no statistical difference in fruit production of woody shrubs on burned and unburned pine plantations in East Texas three years after burning. Dogwood fruiting was increased by winter burning under dense pine-hardwood overstories (Stransky and Halls 1979). These studies indicate that fruit production of most shrub species would be reduced by frequent burning at short intervals since there is a recovery period of l-2 years before production equals or exceeds that of unburned areas.

The increase in abundance and seed production of legumes following fire has been well documented (Stoddard 1931, Cushwa and Reed 1966, Clewell 1966). Stoddard's classic bobwhite quail study showed that populations of the bobwhite quail could not be maintained without regular annual burning. Nearly all the legumes (93 species) and grasses (59 species) used by quail thrive in fire-maintained savannahs. Insects which are an important part of the quails diet also prefer the open, grassland environment created by frequent burning (Romarek 1974).

The red-cockaded woodpecker, an endangered species, generally nests in open, park-like stands of pine with sparse midstories. Prescribed burning is recommended in old-growth pine stands to provide potential nesting habitat by controlling the density and height of the hardwood understory (U.S. Fish and Wildlife Service 1984).

Conner (1981) discussed effects of prescribed fire on snags and cavity trees. Burning may destroy snags which are easily ignited, but it may also kill trees which become snags. Unfortunately, the tradeoff is often large dead snags being replaced by smaller trees killed by fire. Prescribed fires vary in intensity in a random manner, burning hot where fuels tend to be heavy, excessively dry, or highly flamable. These hot spots are where trees are likely to be killed or scarred.

Deer, turkey, and quail are three major game species in Southern forests. They are all favored by the relatively open pine stands and improved browse created by periodic burning. They apparently are favored by the use of broadcast burning to remove logging slash, as well. However, there are hundreds of species in the forest and some may be less favored or actually hurt by regular use of fire. More research is needed to discover how non-game species, as well as game species, are affected by different fire regimes. Requirements of these species must be known before prescribed fire can be used to maintain, restore, or improve habitat for species to be featured in the management program. A recent symposium (Wood 1981) discusses effects of prescribed fire on all forms of wildlife much more thoroughly than space or the author's knowledge allows here.

Water

Effects of prescribed fire on water vary, depending on fire intensity, type and amount of vegetation, ambient temperature, terrain, and other factors. The major problems associated with prescribed fire and water quality are potential increases in sedimentation and, to a lesser degree, increases in dissolved salts in streamflow (Tiedemann et al. 1979). However, most studies in the South indicate that effects of prescribed fire on water quality are minor and of short duration when compared to effects of certain other forest practices.

Brender and Cooper (1968) noted that repeated low-intensity prescribed fires had little effect on hydrologic properties of soils in the Georgia Piedmont. Douglass and Van Lear (1983) monitored water quality of ephmeral streams following two low-intensity prescribed fires in Piedmont loblolly pine stands and detected no significant effects on suspended sediment.

The key to the lack of impact of burning on water quality in these studies is the low to moderate intensity of the fires. Even though the terrain was relatively steep, erosion and sedimentation were not increased. Douglass and Goodwin (1980) have shown that in steep terrain the increase in suspended sediment following management practices is generally related to the amount of bare soil exposed. This would be especially true if the root mat is destroyed by disking or blading. Low intensity flames (1-4 ft. flame length) normally will consume less than half of the litter, and if mineral soil is exposed it is only in small isolated patches in the burned area.

Ursic (1970) measured sediment output from site preparation burning in north Mississippi. Although sediment levels on burned watersheds were several-fold greater than those of control plots, sediment output was only about .5 ton/ac/yr.

Only a few studies in the South have documented effects of prescribed fire on nutrient response in streams or ground water. Douglass and Van Lear (1982) in the Piedmont and Richter et al. (1982) in the Coastal Plain failed to detect any major impact on stormflow or soil solution nutrient levels in response to low-intensity prescribed fire. No studies in the South have examined effects of high intensity slash burning on streamflow nutrient levels. A summarization of the effects of fire on water (Tiedemann et al. 1979) showed that in several cases slash burning in the western United States increased nitrate-N levels in streamflow. In no case did burning cause nitrate-N levels to exceed the recommended EPA standard of 10 parts per million for drinking water. Phosphorus and major cations often increase in streamflow and the soil solution following intense slash fires, but the effects are of short duration and of a magnitude which is not considered damaging to surface waters or site productivity (Tiedemann et al. 1979).

Nutrient loss and stream sedimentation in response to prescribed burning are likely to be of minor impact compared to mechanical methods of site preparation. Observations indicate that even under intense broadcast burns the root mat is often little disturbed and its soil-holding properties are intact. Furthermore, slash tends to be randomly distributed over logged areas, and is seldom completely removed by broadcast burning. Therefore, the root mat, residual forest floor materials, and incompletely consumed slash form debris dams which trap much of the sediment moving downslope (Dissmeyer and Foster 1980). Also, rapid regrowth in the South quickly provides site protection.

Despite speculation that effects of intense prescribed fires are minor on soil and water resources, research is needed to document the magnitude and duration of such fires, especially in the steep terrain of the Piedmont and mountains.

Air

The risk of smoke movement into sensitive areas such as airports, highways, communities, etc. is probably the major threat to the continued use of prescribed burning. Particulates are the major pollutant in the smoke from prescribed burning (Dieterich 1971, Hall 1972, Sandberg et al. 1978). They are complex mixtures of soot, tars, and volatile organic substances, either solid or liquid, and average about 0.1 micron in diameter (McMahon 1976). Under certain atmospheric conditions, i.e., low wind speeds and high humidity, particulates serve as condensation nuclei and result in dense smoke or combinations of smoke and fog. Reductions in visibility during and after prescribed fires have caused numerous highway accidents.

Smoke often accumulates in depressions or along stream channels and other low-lying areas. When the relative humidity approaches 90 percent, which is common during many nights, fog formation is stimulated by the presence of smoke. The combined effects on visibility of smoke and fog is far greater than that of smoke alone. Even smoke from a smoldering fire days old can seriously impair visibility miles away from its origin under certain atmospheric conditions.

Particulates are not the only emissions from fire. Besides carbon dioxide and water vapor, gaseous hydrocarbons, carbon monoxide, and nitrous oxides are also released (Chi et al. 1979). However, only a small proportion (< 3%) of the total national emissions of particulates, carbon monoxide, and hydrocarbons can be attributed to prescribed burning.

Carbon monoxide is a poisionous gas which may reach toxic levels above and adjacent to prescribed fires, but these high concentrations decline rapidly with increasing distance from the flame (Ryan 1974). By burning under atmospheric conditions which encourage rapid mixing, the problem of high carbon monoxide levels can be eliminated.

Hydrocarbons are a diverse group of compounds which contain hydrogen, carbon and their oxygenated derivatives (Hall 1972). Unsaturated hydrocarbons result from the incomplete combustion of organic fuels. Because of their high affinity for oxygen, these compounds may form photochemical smog in the presence of sunlight and oxygen-donating compounds. Methane, ethylene, and hundreds of other gases are released in prescribed burning. Some of these compounds are known to be carcinogenic to laboratory animals, but there is no evidence to show that prescribed fire is increasing levels of these compounds in the environment to dangerous levels. Most of the hydrocarbons released during prescribed fires are quite different from those released in internal compustion engines.

Nitrogen oxides are not likely to be released in health endangering quantities because the threshold temperature for its release is 1540°C (U.S. Department of Health, Education, and Welfare, 1970). Nitrogen gas is volatilized, with the amount released varying with the temperature. At temperatures of 500°C, 100 percent of the nitrogen is volatilized while at temperatures of 200-300°C, only about 50 percent of the nitrogen is lost (Dunn and DeBano 1977). Sulphur dioxide emissions from prescribed fires are of minor importance since sulphur concentration of most forest fuels is less than 0.2 percent.

Because of the serious nature of the effects of prescribed fire on air quality, and its concomitant value as an essential forest management tool, smoke management guidelines have been developed by the U. S. Forest Service to reduce the atmospheric impacts of prescribed fire (USDA Forest Service 1976). This system consists of five steps: (i) plotting the trajectory of the smoke; (2) identifying smoke sensitive areas such as highways, airports, hospitals, etc.; (3) identifying critical targets, i.e., targets close to the burn or those which already have an air pollution problem; (4) determining the fuel type to be burned, e.g., whether the fuel load is light as with a mature pine stand with a grass understory, or heavy as the logging slash following clearcutting; (5) minimize risk by burning under atmospheric conditions which hasten smoke dispersion, or by using appropriate firing techniques and timing to reduce smoke pollution.

CONCLUSIONS

Fire has been a frequent visitor to the southern forests for millenia. Indians and early settlers used it and, gradually, the forestry profession adopted it as an important management tool. In forestry, rather than random woodsburning, prescribed fire was the term coined to describe the use of fire under certain weather and fuel conditions to attain management objectives.

Prescribed fire is used for numerous purposes. It is versatile and cost-effective. Properly planned and executed, prescribed fire has minimal adverse environmental or social effects. Many southern forest ecosystems actually seem to benefit from periodic low-intensity fires, as evidenced by improved habitat for numerous species and improved soil fertility of Coastal Plain sites. Since fire was a major environmental factor in molding southern forests, it is not surprising that these ecosystems are resilient to both frequent low-intensity and occasional high-intensity fires.

Although much is known concerning the uses and effects of prescribed fires, much remains to be learned to fine tune the practice to attain precise management goals. Proper planning, and execution according to the plan, will help to obtain the desired results with minimal adverse effects.

As with other management practices, the use of prescribed fire can be abused. Practioners must be aware of potential damage to forest resources, as well as the possibility of lawsuits from smoke-related accidents, if prescribed fires are not conducted properly. Abuse of the practice is the best way to lose it, and forestry can little afford the loss of such a valuable tool.

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LEGAL IMPLICATIONS OF PRESCRIBED BURNING IN THE SOUTH

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Abstract.--The legal aspects of prescribed forestry burning in the South fall within two major areas. These are: (1) statutory and regulatory constraints imposed by the states and local government, and (2) liability for property damage and personal injury resulting from escaping fire and smoke drift. The current status of the law in both areas is discussed, together with the implications for foresters with silivicultural burning responsibilities.

Prescribed burning has been used by foresters for many years for various silvicultural purposes and is now well accepted professional practice. Resistance to the use of fire from within the forestry community, as well. as from the general public, has virtually disappeared. Prescribed burning is a particularly common and important silvicultural tool in the south where close to 3 million acres of woodland per year are control burned-- about 90 percent of the national total (Sandberg et al. 1979). Aternatives to forestry burning have been the subject of much discussion and conflicting opinion. It is generally agreed, however, that in most instances there are few feasible economic alternatives to the use of prescribed fire in forest and range management. Fire is viewed as an invaluable and irreplaceable management tool. As stated by Cooper (1973), "The overwhelming concensus from foresters is that if prescribed fires were to be outlawed or severely curtailed, we would be confronted with unbearable forest management costs, as intolerable fuel situation that would most assuredly lead to catastrophic wildfires, and a general decline in the productivity of our natural resources."

Prescribed burning, however, is not without its risks. Among the major concerns of those who use this important silvicultural tool are the possibility of civil or criminal liability for bodily injury or property damage, and either civil or criminal liability, or both, for violation of a state or local statute. The very nature of fire and smoke tend to exacerbate this problem-- not only in real terms, but also in the minds of the public who are becoming more aware of environmental enhancement and protection. Foresters who are responsible for prescribed burning need to be cognizant of more than just the technical aspects of the practice. The very real possibility of a lawsuit emanating from a burning operation makes it imperative that the legal implications be carefully considered. Knowledge of the basic provisions of the law associated with the silvicultural use of fire should be as much of a requirement for managing a burn as technical competence.

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The legal aspects of forestry burning have several major components. The first are statutory and regulatory constraints imposed by the various states and, in some instances, county and local governments. These originate from two sources -- air quality legislation and ordinances, and general forestry laws. The two types of statutes often overlap, resulting in a somewhat complex legal framework. Violations may lead to civil or criminal penalties or both.

Air quality[1] laws vary considerably in scope and format among the 12 southern states, although in each the air quality agency has authority to promulgate rules and regulations. A number of the states have delegated this responsibility to their forestry agency, for development and enforcement of prescribed burning regulations. Thus many of the administrative rules that have been issued under the air quality statutes are applicable to forestry burning, although some fail to address the issue in a comprehensive way. General forestry laws in each southern state also apply to open burning. These are not usually concerned with air quality per se, but rather with wildfire prevention.

The result is a varied mixture of statutes and regulations covering prescribed burning that differ widely across the south. The differences are even more apparent among administrative regulations than among legislation (Hauenstein and Siegel 1981). To complicate the issue further, in at least several states local statutes or ordinances may supersede statewide laws.

Legislative Provisions

Many common provisions are found in prescribed burning regulations across the south. For example, a prohibition against using rubber tires, asphalt materials, or other hazardous and smoke-producing agents for starting fires is standard in all 12 states. Rules in most states also address the amount of soil burned in windrows; prevention of smoke hazards near roads, airports and residential areas; and curtailment of burning during air pollution episodes. Some states require either written or verbal permits for all. forestry burning; in others, permits are mandated only for certain areas. Prior notification of intent to burn is required, either by statute or regulations, in most of the southern states. In some, either the air quality or forestry agency is to be notified; in others, adjacent landowners; and in still others, both.

Some states prohibit burning within certain minimum distances of specified land-use areas and limit burning to a specific time period during the day. Several have also placed restrictions on open burning during certain times of the year, mostly because of the widlfire season.

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[1] Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma , South Carolina, Tennessee, Texas, Virginia.

The majority of the southern states do not allow burning during emergency drought conditions, and most have a blanket prohibition against violation of state and national ambient air quality standards, and may require emission monitoring. A catch-all clause is also included in some air quality regulations to prohibit any type of air pollution that constitutes a "public nuisance".

Enforcement and Penalties

Violation of state and local law governing prescribed forestry burning is usually a criminal act. Depending on the state and the seriousness of the violation may be either a misdemeanor or a felony. Conviction of a misdemeanor generally involves at least a fine plus a possible jail sentence of up to one year. The penalty for a felony also nearly always includes a fine, and a prison sentence exceeding one year may additionally be levied. Several southern states impose only fines. Penalties associated with air quality laws are nearly alway heavier than those associated with forestry statutes. Besides criminal prosecution, each southern state may also initiate civil action against a violator to recover damages, administrative expepses and suppression costs that the state may suffer or incur.

In practice, however, restrictions on prescribed burning in the south are generally not severe. Statutory requirements are sometimes loosely enforced. Host of the air quality agencies possess limited jurisdiction and personnel for regulating open burning, while the efforts of many forestry agencies are directed more to preventing and controlling wildfire than to governing controlled burning or protecting air quality. The Laws and regulations that do exist, however, are usually enforced upon complaint. Even then, though, severe penalties are generally not levied even when the law permits large fines and imprisonment. One reason for this is that most prescribed fires are adequately controlled. Another is that they are only a minor source of air pollution and are rarely anything but a purely local matter (Dell 1977). If the contaminent level exceeds state air quality standards, it usually occurs only in the immediate vicinity of the fire which is generally in a rural area. Only a short time period is involved and relatively few people are affected.

For these reasons, many of those who prescribe burn may perhaps tend to be careless in meeting legal requirements. This could be a serious mistake. Although the risk of prosecution may be low and the penalties light, violation of the law can greatly enhance liability of the burner for personal injury or property damage.

CIVIL LIABILITY FOR PERSONAL INJURY AND PROPERTY DAMAGE

A prescribed burn may cause personal injury or property damage in several different ways. Each can result in civil lawsuits against the person or company responsible for the fire even though no state or local law has been broken. The fire may escape from the burner's land, resulting in damage to adjorning property or injuries to persons on that property. Smoke may also result in civil liability, even though the fire may be confined to the premises of the burner. The common and serious smoke problem has been reduced visibility. Dense smoke on public roads originating from silvicultural burning has caused a number of automobile accidents resulting in injury and death. Smoke drift has also affected airport traffic. The problem is most severe when smoke becomes mixed with fog during atmospheric inversions.

Visibility reduction may also have aesthetic effects, although legal actions on that basis are not nearly as likely.A third area of potential liability from smoke drift concerns its status as a health hazard. Particulate matter concentration in excessive amounts, and over prolonged time spans, has been significant ly correlated as a health hazard--particularly for more susceptible individuals such as hospital patients, the elderly, or those with respiratory disorders (Cook et al. 1978). There have been several incidents in the south where smoke from prescribed forestry burning has been sucked into hospitals and other buildings by air conditioners.

Most forestry smoke problems have occured near urban areas that were already overloaded with air pollutants. Woodland acreage close to these nonattainment areas has been placed under increasing burning constraints in recent years. As the more obvious sources of air pollution are controlled, the impact of smoke from silvicultural burning as an air pollutant is certain to come under ever closer scrutiny (Mobley et al. 1975).

Basis of Liability

The liability resulting from injurious effects of prescribed burning is both a matter of statutory provisions and case law. The well established general rule is that when a property owner sets a fire on his own land for a lawful purpose, he is not--in the absence of a law to the contrary--liable for damage or in jury caused by the fire spreading to another's land, or from[2] drifting smoke, unless he was neligent in starting or controlling the fire. What is meant by negligence? Simply stated, it is failure to exercise the degree of care that the situation requires. This is sometimes called ordinary care, or the care that would be taken under the circumstances by a prudent and reasonable person in order to prevent property damage or injury. A finding of gross negligence--which means flagrant or extreme negligence--is not necessary in order to prove liability in conjunction with a prescribed burn.[3] Ordinary care is generally a question of fact in each individual sitation unless established otherwise by statute. What does this mean?

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[2] See Bower and Johnson Construction Co. v. White., 255 F.2d 482 (applying Mississippi law); Bush v. Dania (Fla.App.),121 S02d 169; Pelloquin v. Mission Pacific Railroad Do. (La. App.), 216 S02d 686.

[3] Morrow v. Johnston, 68 SE2d 906.

Negligence per se.--Some states specify directly in their air quality forestry burning legislation that a violation of the law constitutes negligence per se. Therefore, in those states, if property damage or injury results from a prescribed fire where the law was not followed in some particular aspect, the burner is automatically negligent and responsible in damages. A determination of whether ordinary care was met, by examining the facts and circumstances of the situation, would not be necessary. Even in some states without such a statute, the courts have held that failure to obey the law constitutes negligence per se. For example, it has been ruled by the courts in several southern states that failure to obtain a required burning permit automatically constitutes negligence, as does failure to notify an adjoining landowner as mandated by law.

Proof of negligence.--But what about those situations where the law has been followed in all respects, but injury or property damage still occurs? Here the burden is usually on the plaintiff--that is, the person bringing suit--to prove negligence on the burner. There is some authority to the contrary, however, in those instances where a person is authorized to set a fire only under certain circumstances. The burden of proof in some jurisdiction then rests on the defendant. In either situation, however, the spreading of fire or smoke from a legally set fire to another's property is not evidence of negligence in itself. And, as a general rule, it is not necessary to establish negligence in both setting the fire and in controlling it. Only one or the other is required. Also, the manner in which fire or smoke spreads is immaterial in determining liability.

Defenses Available to the Defendant.

A number of defenses to a finding of negligence may be available to a defendant burner. Several of the more important will be discussed.

Wind as an intervening cause.--The most common intervening cause raised as defense to a charge of negligence in burning is unexpected wind. To prevail, however, the defendant must show that the wind arose after the fire was set, that it was extraordinary in scope, and that it could not have been reasonably anticipated in that locality at that time. If this is done, and the person doing the burning has absolutely no control over the situation, the wind is recognized as the proximate cause of the injury or damage, relieving the defendant. Unless those factors can be proven, though, wind is not ordinarily recognized as being the type of intervening cause that will disprove negligence--nor will it do so if, after the wind arises, the defendant becomes negligent at that time or fails to do all that he can to prevent the spread of the fire and smoke.[4]

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[4] See Bushnell v. Telluride Power Co., 145 F.2d 950.

There have been court decisions on wind associated with prescribed burning in a number of southern states--including Mississippi, North Carolina and Georgia.

Contributory negligence.--Contributory negligence on a plaintiff's part, if proven, will lessen a defendant burner's liability. The extent to which liability is decreased will depend on the degree of planitiff negligence, and is a question of fact in each particular situation. For example, willfull failure by an adjoining landowner to act against a spreading fire has been held to be contributory negligence. On the other hand, in another decision, the plaintiff was not negligent in maintaining an open, oilsoaked ditch near a building because he could not have reasonably foreseen that the defendant would permit the fire to cross the property line.[5] With respect to highways obscured by smoke, the general rule is that a motorist is not necessarily required to stop but only to exercise care and caution commensurate with the prevailing conditions. If he fails to do so, and an accident results, he may be contributorily negligent.

Action' employees and independent contractors.--It is well established that if an employee of a landowner prescribe burns during the scope of his employment, even though not specifically authorized to do so, the employee is liable for any damage or injury that may result. The employer is generally not liable, however, if the employee has set the fire for personal reasons not within the scope of employment. The situation with an independent contractor is somewhat different. If an independent contractor prescribe burns, the landowner's liability for the contractor's actions depends on the degree of control exercised by the landowner over the contractor. If there is little or no control, the landowner is usually not held liable. In a few jurisdictions, however, degree of control is not a factor--the legal concept of nondelegable duty governs.That is, the landowner is responsible whether control is exercised or not. In a related situation, there have been several. court decisions holding that even though the landowner's burn was entirely planned and supervised by an independent forester , with no control by the landowner, that the landowner was liable for damages because he failed to take the necessary actions of a prudent man when the forester did not.

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5 Mutual Fire Insurance Co. v. Willis, 179 SO2d 441.

6 See Wofford v. Johnson, 164 SO2d 458.

7 See Hanks v. Christensen, 354 P2d 564, 11 Utah 2d 8.

LIABILITY FOR FIRE FIGHTING EXPENSES

A number of states have laws that impose liability on a landowner for fire fighting expenses when his prescribed burn spreads to another's property. This liability is di.sti.nct from that levied for personal injury or property damage. These statutes have generally been upheld by the courts as a valid exercise of state police power when the liability has been predicated on the negligence of the landowner or his failure to comply with the law.

LIMITING LIABILITY

The obvious first action to take for limiting liability in conjunction with prescribed burning is to obey all laws and regulations governing the situtation. Over and above this, however, there are a number of other precautions which may serve to mitigate liability to some extent, depending on the particular state and the circumstances involved.

For example, many southern states have established voluntary smoke management programs that utilize a number of optional restrictions on open burning in addition to the mandatory constraints imposed by law. The programs range in complexity from those which utilize computer systems and statewide communications networks to those that merely provide lists of basic suggestions for use by field crews when burning (Paul et al. 1978). Following such guidelines can not only help to prevent sistuati.ons that give rise to liability for fire spread or the harmful effects of smoke, but can also go a long way toward establishing the degree of care necessary to disprove negligence. This would seem to be particularly true if a formal plan is developed that includes the use of local weather information and air quality indices. And, of course, the U.S. Forest Service's Macon Fire Laboratory has developed a detailed screening system for determining whether or not to burn which is published in the Southern Forestry Smoke Management Guidebook (Mobley 1976).

CONCLUSION

The forestry community in the south should be aware that existing state laws and regulations governing prescribed forestry burning can be strengthened or more severely enforced, and that new statutes and rules can easily be promulgated. This could occur as the public becomes more concerned with air pollution and other smoke problems, and if these is increased unfavorable publicity over negligent injury and property damage resulting from prescribed fire. The primary concern for forestry practitioners is the possibility that such a situation would produce unmanageable regulation of forest practices. Most foresters in the south are of the opinion that an increased use of voluntary programs which utilize recommended guidelines, training, and education is the preferable alternative and will serve to offset any trend to more regulation. If serious smoke and fire problems associated with forestry burning are to be minimized by voluntary means rather than by law, however,the forest industries and the state forestry agencies will have to lead the way in promoting fire and smoke management. The unwelcome alternative is more regulation with all the negative impacts that the word implies.

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AERIAL IGNITION
(Ping-Pong Balls)

J. W. Gnann[1/]

Abstract.--Aerial ignition using plastic spheres (similar to ping-pong balls) charged with potassium permanganate activated by ethylene glycol and dropped from a low flying helicopter is a proven system to safely prescribe burn large areas in a short time for rough reduction and site preparation without causing significant direct mortality to wildlife.

Additional keywords: Aerial ignition device, dispenser, spotting, Pacific Forest Research Center, site preparation burn.

INTRODUCTION

Prescribed fires that can be used without causing undue damage to the overstory while consuming the litter on large acreages in a short time was needed to reduce fire hazard, lower site preparation cost, and to backfire on wildfires. This technique had to be cost effective, environmentally acceptable and readily available.

The Australian forester, during the early 1960s, accepted the challenge and developed a spot-firing technique whereby ignition devices were dropped from aircraft onto 5,000-10,000 acre blocks of eucalyptus forests to consume the litter and reduce the fire hazard (Baxter et. al 1966).

The early system initiated by the Australians consisted of a small plastic capsule containing potassium permanganate. A syringe was used to inject ethylene glycol into the plastic capsule. The charged device was dropped from an aircraft. The exothermic reaction resulted in spot fires where the device landed.

Using the Australian ignition device and incorporating some new ideas and techniques from many sources, the Canadian Forest Service developed the present Pacific Forest Research Center (PFRC) dispenser.

The pharmaceutical vials used by the Australians to contain the potassium permanagante were satisfactory for manual dispensers, but their irregular shape caused malfunctions when used in faster machines (Lait & Taylor 1972). A spherical container was introduced by the Alberta Department of Lands and Forest, Equipment Development Section. This container was modified for use in the PFRC dispenser; the final product termed AID (Aerial Ignition Device) is in use today.

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The PFRC dispenser mounted in a Huey Model UHIB helicopter, using AID igniters burning areas having heavy fuel accumulations can be fired at a rate of up to 15 acres per minute (J. F. Sain, 1979).

Today there are 30 PFRC dispensers in operation in the United States, of which 10 are in use in the South; 40 in Canada; 2 in Australia; for a total of 72 worldwide.

Mark II Aerial Ignition Dispenser and Aerial Ignition Device

The function of the dispenser is to inject the ethylene glycol into the AID that contains potassium permanganate thereby initiating the exothermic reaction. The main components of the dispenser consist of frame, slipper blocks, motor, tank and injecting system. The dispenser receives the AID injects ethylene glycol and releases the AID in a smooth continuous motion. Figure 1.

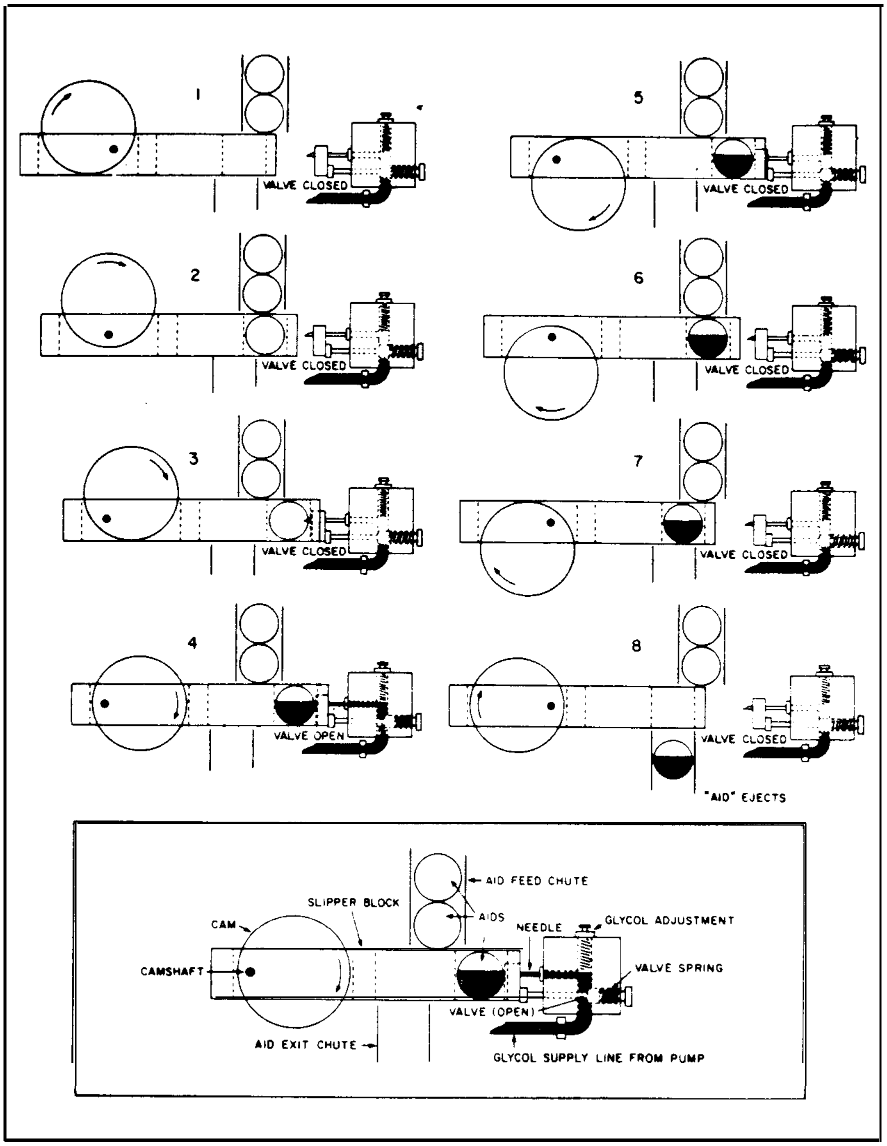

Figure 1. Schematic of slipper and valve block assembly with an eight step sequence of one revolution of a cam.

The aerial ignition device (AID) consists of 3.5 grams of potassium permanganate contained in two permanently sealed hemispheres made of high impact polystyrene. Each AID is sphere shaped, 1.25 inches in diameter. As the AID moves through the dispenser it is penetrated by a hollow stainless steel needle and 1 Ml of 50% water, and ethylene glycol solution is injected. The AID is then dropped from the dispenser and the subsequent chemical reaction produces ignition in about 25 to 30 seconds (Lait & Muraro, S.).

Aircraft

The Pacific Forest Research Center dispenser has been successfully mounted in several models of helicopters including but not limited to the Huey Model UHIB, Bell 206 Jet Ranger and the Hughes 500. The door is removed and the dispenser is mounted in the door of the helicopter with the discharge shoot extending out of the door. The dispenser is mounted in such a manner that it can be jettisoned in case of a malfunction or fire.

The flying crew consist of an aircraft pilot and a dispenser operator. An observer may also be used, but is not necessary if the pilot is provided with adequate maps and is familiar with the boundaries of the site to be burned.

Planning the Oneration

To expedite the burning program, the areas scheduled for a burn should be identified well in advance. Sufficient areas to accommodate at least a days work should be secured with fire lines where needed. One of the more costly items in aerial burning operation is the helicopter and crew. Therefore every reasonable effort should be made to effectively utilize the aircraft. Ferry time should be kept to a minimum, planning the work in a systematic manner can help accomplish this. A nearby heliport is desirable to reduce ferry time, to refuel, and pick up supplies.

There should be a standby ground crew and equipment necessary to backfire the initial firing line if needed, and to contain any fire that may escape from the prescribed burn area. Such precautions are essential for the success and safety of any aerial ignition operation.

Weather

Environmental constraints must be considered when planning any prescribed burn. Air quality, smoke sensitive areas, and safety are foremost in the initial planning phase of the burning operation.

The objective of the burn will determine what weather conditions can be tolerated. If a site preparation burn is needed, the objective is a hot fire to consume logging slash. Conversely a rough reduction burn under an established stand must consider the amount of scorch considered acceptable. The height of the overstory canopy, the diameter of the trees, the fuel loadings, and the slope all enter into the formula to arrive at weather parameters that could be tolerated. For example, slash pine stands in the Georgia Coastal Plain with no more than 3 years of fuel accumulation can be prescribed burned without excessive scorch if fired within three days of at least 0.5 inches of rain, when the relative humidity is between 45 and 60 percent, ambient temperature is under 60°F and average stand height exceeds 35 feet. In essence the amount of fuel available for combustion is being controlled through fuel moisture control. The same approach can probably be followed with older rough accumulation, but the chances of developing excessive heat are much greater (R. W. Johansen, 1984).

In younger stands with heavy fuel accumulation the technique of firing the stand early in the morning while the fuel is still wet with dew and the air temperature near freezing has been successfully tried.

Detail weather prescription for each fuel type, fuel loading and timber size has not been developed. History, experience and follow-up to evaluate the burn are invaluable in developing guidelines. When understory burning is planned, weather condition of 50% relative humidity, 50°F ambient temperatures, 8-10 mph breeze and several days following a rain is a good reference.

Firing Techniques

The base line may be hand fired if there is a risk of the aerially ignited fire escaping the designated area to burn.

The helicopter will begin firing on the down wind side of the tract and work upwind.

The ignition points should be placed on a square grid.

Spotting density within the range of lch x lch and 4ch x 4ch had little effect on flame height, and scorch height on a slash pine stand 35' in height burned in South Georgia (R. W. Johansen, 1984).

The spotting density has a big impact on cost of burning, and burn out time. In many situations three to four spots per acre will result in a satisfactory burn.

The maximum flying speed of the helicopter should be less than 50 MPH while fire-spotting operation is in progress.

A flying height of 200-300 feet provides good overall visibility of ground condition, and a safety margin for aircraft emergency procedure without sacrificing ignition accuracy.

Fire Behavior

A study in coastal Georgia gallberry - palmetto type indicated that there is no definite correlation between spot spacing and any of the fire behavior parameters measured, even though there was a sixteenfold difference in spot fire density between 1x1 and 4x4 chain plots. (R. W. Johansen, 1984).

Wildlife

Wildlife professionals generally agree on the benefits to wildlife from prescribed burning in the South. Very few are familiar with the aerial ignition technique or its immediate effect on wildlife.

To answer some of the questions concerning the effect aerial ignition burning has on wildlife, a study was made on Union Camp Corporation land in coastal South Carolina in cooperation with the South Carolina Wildlife and Marine Resources Department. The study area was surrounded by observers, the area was ignited, a count was made of numerous game animals fleeing the study area, including deer, turkey, hogs, rabbits, and birds. A survey was made of the areas after the burning was completed, and it was concluded that aerial ignition prescribed burning did not cause significant direct mortality to wildlife (Folk & Bales 1983).

Safetv

The following precautions must be followed to promote a safe operation:

1. The AIDS dispenser SHOULD NOT be permanently affixed to the helicopter. It should be mounted with straps that to be cut to jettison the dispenser in case of malfunction.
2. The glycol tank must be filled and tightly capped away from the aircraft.
3. Lead acid batteries MUST NOT be carried in the cabin.
4. Have a fire extinguisher available.
5. Extra supplies of glycol MUST NOT be carried in the cabin.
6. A metal container must be on hand for testing and containment of malfunctioning AIDS.
7. Ignition time should not be less than 20 seconds.
8. Maximum speed of a Bell 206 or Hughes 500 shall not exceed 50 MPH while dropping operation is in progress.
9. Do not remove AIDS feed chute while in operation.
10. Potassium permanganate is a strong oxidizer and therefore should be stored in a cool dry place (refer to Operations Manual for details).
11. Smoke should be kept away from smoke sensitive areas such as highways, towns, airports.
12. The area to burn must be clear of people and equipment.
13. Keep burning within designated area.

Advantages

1. Burn large areas in a short period of time with minimum damage to the stand.
2. Good burning weather can be better utilized.

3. Burn smoke sensitive areas more safely.

4. Can resume burning sooner after a rain.

5. Helicopter that initiates the burn can also serve as reconnaissance aircraft.

Disadvantages

1. More costly than hand firing.

2. Experienced contractors are in short supply.

3. Cost is very high to burn small blocks.

4. Smoke plume generated by this firing technique is very large and attracts attention.

5. Requires detail planning.

General

Approximately 120,000 acres were prescribe burned in the South last year using Aerial Ignition Device (AID).

The cost is influenced by the size of the tract to be burned; the larger the tract, in general, the lower the cost. The cost for aerial ignition burning ranges from $2.00-$3.50 per acre, which may be higher than hand firing in most instances.

The newest dispenser available is the "PREMO MARK III". This tool is available from Premo Plastics Engineering, Ltd. - 863 Viewfield Road, Victoria, B.C., Canada, V984V2 and Aerostat, Inc., Leesburg, Florida.

The Mark III dispenser sells for approximately $5200.00 plus duty and freight. The AIDS are $105.00 per M plus duty and freight.

CONCLUSIONS

Prescribed burning with the AID dispenser is an efficient tool that can effectively burn large acreages in a short period of time. The cost is generally higher than hand burning, but the method is more efficient in that larger acreages can be burned in shorter period of time during ideal burning conditions, and a better rough reduction burn can be achieved.

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AERIAL IGNITION FLYING DRIP TORCH

Grady E. Srevens[1]

Abstract.--Aerial drip torch devices have potential for dramatically increasing acreage burned annually. Aerial burning requires different and broader concepts than hand burning, more advance planning, more attention to detail, and at least a basic understanding of helicopter operations.

Additional keywords: Preparation, coordination, communications.

INTRODUCTION

Several aerial ignition devices have been introduced within the past 20 years. The aerial drip torch concept has been a progressive expansion of technology that began with the hand-held backfire torch. Use of the aerial torch has not, however, kept pace with the potential provided by the expanded technology. Improvements in drip torch modification will continue with acceptance of it as a management tool.

Aerial ignition allows rapid burning of large acreage or numerous tracts on the limited number of days with good burning weather. The technique normally decreases the risk of on-the-ground safety hazards experienced with hand burning. Prescribed fire, either alone or in combination with herbicides, can decrease site degradation often inflicted by mechanical site preparation. Aerial burning allows access to interior areas not normally accessible during hand burning. Aerial burning allows more rapid burning of a given tract resulting in shorter duration of fire and smoke emission. Helicopter pilots can locate potential trouble areas and can also use a water bucket to drop water on spotovers.

HISTORY

The first "helitorch" was developed by John Muraro of Pacific Forest Research Center, Victoria, B.C. (Johansen, 1984). This device was simply a large backfire drip torch suspended by cable from a helicopter. Early problems with it were ignition system difficulties, atomization and oxygenation of the fuel mixture prior to it reaching the ground, plus dangerously low and slow helicopter flight.

Aerial torches progressed from the original concept of a gigantic backfire torch to present day on-board systems. The first large backfire

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torch was a 30-55 gallon drum bolted to a heavy angle iron frame (see Figure 1). Fuel (60% diesel/40% gas) flowed through common plumbing hardware and dribbled and/or poured out the end of a l-inch pipe. The system was ignited by auto spark plugs which proved unreliable. Helicopters had to be flown at slow speeds and very low heights for the liquid fire to reach the ground. Despite the problems encountered, aerial burning became an instant success.

Gelled gasoline was the next logical progression. With this mixture the system could be flown faster and higher with more fire reaching the ground and burning longer to ignite ground level fuels. Modifications to the torches to utilize "jelly-gas" included the addition of a pumping system, flow control devices and positive electronic ignition. The first helitorch using gelled gasoline was developed by Western Helicopter Services, Incorporated (Johansen, 1984).

Several operators are now using gel systems.either manufactured to their specifications or purchased from a commercial manufacturer (i.e., Simplex[1], 13340 N.E. Whitaker Way, Portland, Cregon 97230). Gel aerial ignition systems (commonly called jelly-gas torches) require specific considerations. Most drip torch operations use regular gas mixed with Alumagel, a dry metallic stearate that is available from WITO Chemical Corporation, Organics Division, 3230 Brookfield Street, Houston, Texas 77045. The latest price, September 1984, is $2.08 per pound. The recommended mix is 1 pound of Alumagel to 5 gallons of gasoline. Temperature, humidity, brand of gasoline, method and duration of mixing and length of set-time influence the quality of mixture. Risks commonly associated with gasoline usage need to be evaluated carefully and all precautions taken.

PRACTICAL OPERATIONS

The author will not attempt to cover basic fire plans but will offer suggestions to optimize helicopter utilization. Considerations will vary from state-to-state and company-to-company.

The preplan of the Fire Boss should include preselection and preparation of the heliport. The heliport should not be located on the site to be burned or where smoke drift could obscure the heliport area. Try to situate heliports in close proximity to work area. Less ferry (deadhead) time means more work time, which means greater productivity per flight hour and lower cost per acre. Heliports must be accessible by helicopter support vehicles.

A pre-ignition briefing with the pilot is essential. This discussion should include your basic plan, information on the area to be burned, potential problem areas, hazards and water sources for the bucket, if available.

A plat with the above information shown on it and corners or prominent terrain features numerically or alphabetically labeled for everyone to

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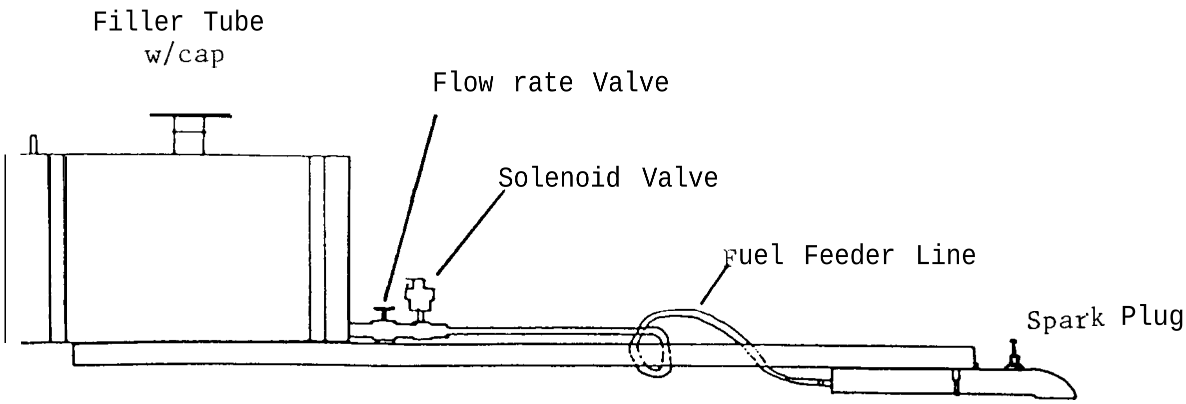
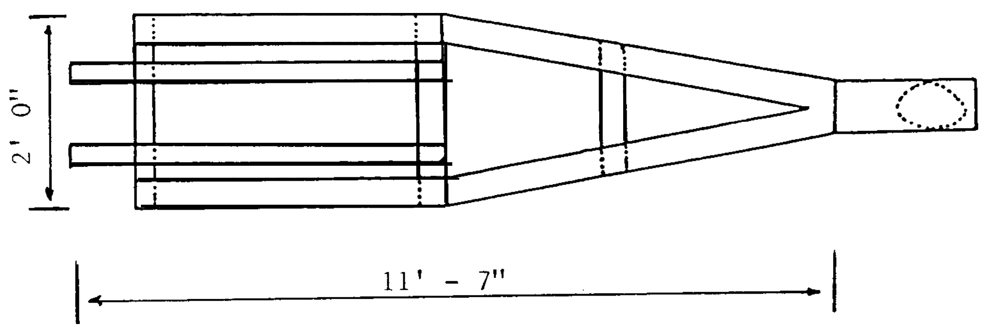
[1]The mention of products or trade names in this paper does not constitute an endorsement by International Paper Company.



DRIP TORCH - SIDE VIEW



DRIP TORCH FRAME - TOP VIEW

Figure 1. Aerial Torch

readily reference is essential for good control and a safe operation. A suggested example of a properly prepared map is shown in Figure 2.

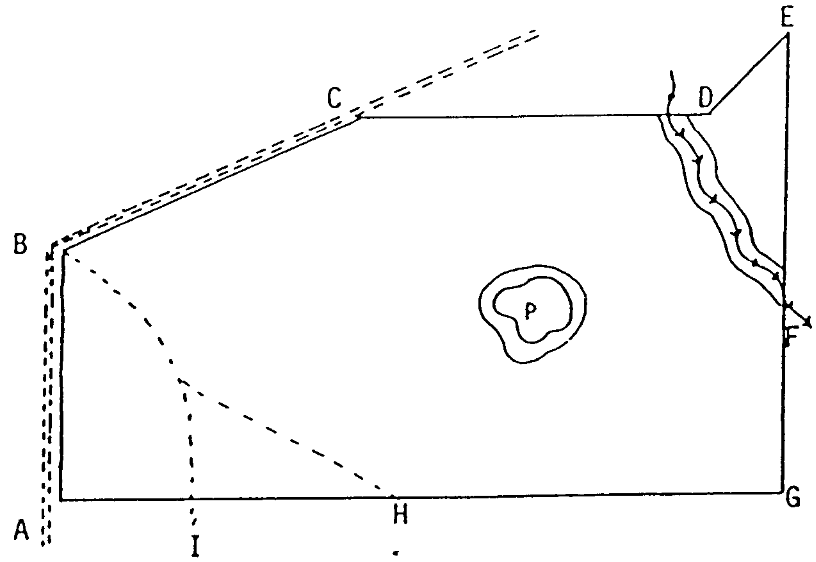


Figure 2. Example of map to be prepared for burning operation.

Radio communications between air and ground crews should be mandatory in all aerial forestry operations. Try to specify this fact when negotiating your contracts. Two-way radios not only assist in command and control but far outweigh the expense involved when considering safety. Other safety considerations around the helicopter are shown in Appendix 1.

If needed, hand backfires should be set as early as possible to optimize helicopter time. Areas likely needing hand backfire are meandering fire lines, plowed-only lines, and other critical areas. Backfires should be set according to wind direction so that the area to be burned is not covered with smoke. Roads and bladed lines make the best firebreaks. Bladed lines should be constructed as straight as possible.

Consider using two or three tractor/crew units and leapfrogging these units for optimum burned acres per helicopter hours. For example, start burning at tract A with tractor unit 1, while unit 2 is standing by at tract B. After securing tract A, leave unit 1 to "mop-up" while the helicopter proceeds to tract B and begins burning. Before completion of tract B, unit 1 can usually move into position at tract C and continue to repeat the leapfrogging process.

Ground crews must understand that the aerial torch and water bucket are only tools to assist their normal job requirements. One of the biggest misunderstandings is to assume that the helicopter will do everything--set the fire, patrol the area, douse breakovers--and that the ground crew can sit back and take it easy.

LEGAL CONSIDERATIONS

Sling loads with aerial torches are legal under FAR part 137, Aircraft Agricultural Operations, because aerial burning is an approved economic practice on timberlands. Regulation FAR part 133 pertains specifically to helicopter sling-load operations but is normally not needed for using sling aerial torches. If the operator has an on-board system, then he needs FAA 337 local approval in addition to his 137 certificate. Anytime a pilot is paid for a contract operation, he should be commerically licensed. He also needs a current minimum Class II physical.

The helicopter contractor should provide at least minimum liability insurance (set by each state). Customers of the contractor should have insurance coverage providing higher limits of liability. Regardless of insurance coverage, helicopter slings should never be operated in a manner that could endanger life or property.

SUMMARY

Increased acceptance by landowners, improved equipment, and new techniques will contribute to aerial burning effectiveness. A basic understanding of this proven tool and proper application of the technology will result in better quality and safer burns with lower per acre cost.

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APPENDIX 1

Helicopter Safety Rules

1. Never walk to the rear of the helicopter.

2. Get clearance from pilot before approaching or leaving the helicopter. Stay in a 45° arc to the right or left of the nose of the helicopter.

3. Crouch when leaving or approaching the helicopter.

4. Always wear seat belts and secure door.

5. Ensure that seat belts are locked inside and the door secured when leaving helicopter.

6. No smoking at heliport or during takeoff or landing--smoke airborne only with the pilot's permission.

7. No hard hats in the vicinity of the helicopter without secured safety straps.

8. No loose articles or clothing in the vicinity of the helicopter.

9. No unsecured gear stowed on the helicopter.

BE ALERT AND LIVE AROUND THE HELICOPTER!

FIRE SCIENCE ADAPTATIONS FOR THE SOUTHEASTERN U.S.--A RESEARCH UPDATE 1980-1984

DALE D. WADE[1]

Abstract.--Fire Science Research Work Unit accomplishments 1980-1984 are summarized and publications listed. Current fire behavior and fire effects investigations are briefly described.

INTRODUCTION

One of the most important resource management challenges facing the South is to provide a greater share of the Nation's wood fiber from a shrinking forest land base (e.g. see Barras 1984). The intentional use of fire not only can, but must play a greatly expanded role if this challenge is to be met.

During an average year, slightly more than 50 percent of the Nation's wildfire acreage is in the 13 Southern States. An alarming proportion of this acreage occurs in young pine plantations where damage is often severe. The magnitude of these losses is much greater than generally realized. For example, during the 1976 fire season, close to 30,000 acres of pine, with an average age of 6 years, were blackened (Wilson 1977). And during the first 10 months of 1981 an estimated 75,000 acres of l-10 year old pine plantations were burned in the 13 Southern States (U.S.D.A. Forest Service 1982). Protection of the roughly 19 million acres in pine plantations and the 42 million acres of natural pine in this region should thus be a top priority.

How Can Prescribed Fire Help?

Prescribed fire is the only practical way to reduce the fuel hazard in established pine stands, but less than 4 million of the 61 million acres are intentionally burned each year. Moreover, fire is seldom prescribed in young pine stands where the damage potential from wildfire is greatest.

Prescribed fire can also increase tree growth rates by controlling understory vegetation, especially in young pine stands. In the South, prescribed fire has been used for over three centuries to control undesirable vegetation. A major advantage of it over other alternatives is that, depending upon timing and firing technique, many plant species can be controlled rather than eradicated. Fire enhances diversity by increasing legumes and other plants eaten by wildlife such as quail and turkey. Succulent sprout growth is also promoted and the plants are kept within reach of browsers such as deer.

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A third major area where prescribed fire increases productivity is in preparing sites prior to planting pine, which is an almost mandatory practice in the South to set back hardwoods that compete with the pine seedlings. This need is especially great on the more marginal sites that continue to be put into timber production (Guldin 1984). Currently fire, machines, chemi.cals, or some combination of these methods are used, but, if the costs of diesel fuel and heavy equipment continue to escalate and herbicide restrictions continue to tighten, fewer acres will be treated with chemicals and heavy equipment. Thus, if productivity is to be increased, the use of low cost, efficient alternatives such as prescribed fire will also have to increase.

CURRENT RESEARCH

The research mission of Research Work Unit-2111 in 1980-1984 has been to develop, adapt and incorporate into cost effective methods the fire science information necessary to expand the use of prescribed fire in southern forests. On holdings where prescription fire is routinely used, we are developing the information that will enable a substantial increase in the area that can be safely treated on the few ideal burning days that occur each winter as well as developing the data base neoessary to widen the prescribed burning window .

On forest land currently being managed without the benefits of prescribed fire, our goal is to better quantify the behavior and effects of fire, and demonstrate its predictability.

Research to accomplish these objectives is grouped into three broad areas:

1. The evaluation of spot firing techniques
2. The development of methods for predicting fire behavior and effects
3. The quantification of the effects of fire on vegetation

Ongoing research in each of these areas will be briefly described.

Evaluation of Firing Techniques

This broad topic area has been divided into (1) assessment of aerial ignition guidelines and (2) comparison of the behavior of spot-and line-ignited fires.

Aerial ignition guidelines .--Using conventional ground ignition methods, resource managers rarely have enough good burning days during a given year to treat the acreage scheduled. As the number of possible days remaining decreases, managers often attempt to use marginal weather conditions, with results ranging from a simple decrease in benefits to an unacceptable increase in deleterious side effects. The temptation. to use marginal burning conditions could be virtually eliminated by the development of dependable, cost-effecti.ve aerial ignition techniques. Aerial ignition has numerous advantages over ground ignition, but perhaps the most important is the enormous increase in acreage that can be treated during a given burning period. Increases in safety and efficiency , and the potential for a substantial reduction in overall cost make aerial ignition all the more attractive.

Both the aerial ignition device (A.I.D. or "ping-pong ball") system and helitorch or "flying drip torch" system can be used to ignite spot fires. Individual spots simultaneously head, flank, and back as they grow and eventual ly burn into each other. We have developed preliminary criteria for spacing igniters in southeastern fuel types (Johansen 1984a, 1984b) and evaluated different helitorch equipment configurations (Johansen [In press]). Frevious work (Sackett 1968) showed a direct correlation between the number of ignition points per acre and the amount of crown scorch, but under the spot fire ignition grids (1 ch. x 1 ch. to 4 ch. x 4 ch.) and burning conditions used in our present studies, we found spac ing had little ef fect on scorch height. The operational ramification of these results is to use the 4 ch. x 4 ch. ignition grid because it requires less flying time and fewer ignitions. In our stud ies , undesirable flame heights and attendant crown scorch were associated with spot fire merger, particularly on rectangular grids where the flanks of spot fires along a given ignition line tended to come together before the heads ran into the backfires from the next downwind line of spots.

Differences in burning conditions may account for the contrast between our results and those of earlier studies. Most of our fires took place at the "high" end of the prescribed burn scale. The forward rate of spread of the individual spots increased from 8'/min. in the 1 ch. x 1 ch. spacing tests to 14'/min. in the x 4 ch. x 4 ch. spacing indicating that intensity continued to increase as the spots spread. Thus the increased intensity of the individual spots at the wide spacings compensated for the reduced merge line distances resulting in about the same degree of scorch regardless of spacing.

We cannot tell from these study results what the effects of ignition grids wider than 4 ch. x 4 ch. would be or what the effect of different fuel moisture and weather conditions on spot fire behavior would be.

Eecause our suggested 4 ch. x 4 ch. grid which results in only 1 ignition per 1.6 acres and because the sphere of influence of each igniter is only slightly larger than a ping-pong ball, this system is best for continuous fuels. The flying drip torch emits a steady stream of burning fuel globs which provide many more potential ignitions per unit of line flown. This system thus works well in discontinuous fuels such as are found in many clearcuts. When the flying drip torch is used in continuous fuels, the many ignitions per unit of flight line rapidly establish a line of headfire witb its associated higher intensities and potential for higher scorch than does the ping-pong ball system under the same conditions.

Spot vs line fire behavior.--Although early controlled burns were spot fires, they were replaced by line fires with the introduction of the drip torch. The behavior of spot fires therefore has been virtually ignored except in the unique ecosystems of South Florida where Everglades National Park in cooperation with the Southern Forest Fire Laboratory pioneered the use of aerial ignition in the South. (Sackett 1975; Wade, Ewel & Hofstetter 1980).

The behavior of spot fires under various weather and fuel conditions must be determined before guidelines relating ignition point density to fire parameters such as intensity and burn-out time can be established. Information on fuel consumption and emission rates is also needed to calculate air-quality impacts. In my judgment, the use of weather conditions normally considered ideal for line-ignited backfires is the major reason some aerially ignited burns have produced intensities above those called for in the prescription.

With spot firing, most of the area is burned by headfires, which spread faster and are more intense than line ignited-backfires, although they are not as fast, or as intense as line headfires.

Spot fires don't have to be ignited from the air to be effective. For example, the Oconee National Forest has implemented a burning program in Piedmont fuel types using strip headfires. This firing technique necessitates a halt in ignition whenever conditions get too severe--as often occurs during the heat of the afternoon. Ignition can generally be resumed in the evening but this is outside normal work hours and smoke dispersion is generally poorer at night. Backfires aren't practical because of the lack of interior plow lines. Consultation with our Research Work Unit resulted in a novel solution; now whenever line headfire behavior becomes too intense, the firing crew simply switches to spot fires. Torch people walk the same distance but instead of stringing a line of fire, each ignites a spot every so many paces. This technique also allows more area to be ignited between torch refills.

Future work.--Because aerial ignition is rapidly replacing line firing on many agency and industrial land holdings in the South, operational guidelines are urgently needed. Moreover, many managers still have a nagging fear regarding damage that might occur from having too many spot fires burning on a given area at the same time. I believe the greatest potential of aerial ignition is on the damper end of the prescribed burning window, where individual spots will not merge into an uncontrollable inferno. But, if this phenomenon is to be avoided, threshold conditions for its development should be established.

Methods For Predicting Fire Behavior and Effects

If the South is to meet its wood fiber production goals, better protection and increased growth rates of existing stands will be mandatory, and the judicious use of prescribed fire is perhaps the most economical means of accomplishing these tasks. But how can this tool be sold to the managers of the tens of millions of acres where it is not currently used? The reasons for not using fire where it has obvious potential are varied and include misconceptions or ignorance regarding the benefits of prescribed fire. However, I believe a major reason is simply that these landowners attach a subjectively high probability to the potential for resource damage and litigation. While qualitative guides (e.g. Mobley et.al. 1978) have sufficed for those now using prescription fire, we need site-specific predictors of fire behavior and effects that work under a wide range of fuel and weather conditions in order to expand the window of opportunity for prescription burning. Researchers have attempted to devise fire damage prediction systems based on measures of fire intensity for over 50 years, but solutions have proved elusive. One stumbling block has been the lack of a good method for rating the behavior and effects of prescribed fire. There would be numerous advantages to adapting an existing, commonly used, fire intensity predictor such as flame length.

Flame length-- The use of flame length as an indicator of fire behavior has received wide acclaim since Byram (1959) published an equation relating flame length to fireline intensity. The concept is appealing, but length has proved to be exceedingly difficult to measure accurately. Johnson (1982a) found that actual flame length measurements did not agree with predicted values based on existing equations that express the relationship between fire intensity and flame length . More recent work, however, suggests that flame lengths were simply not measured accurately enough.[2]

Fuel weight.--Fuel consumption is another fire behavior descriptor. This parameter is dependent upon total fuel which is itself usually predicted. Generalized prediction equations for southern fuel complexes exist, but there is much room for improvement.

We are using our archived forest floor fuel data to develop more accurate litter weight accumulation prediction models for loblolly, longleaf and slash pine based on age of rough and stand basal area. Information regarding shortleaf pine has already been published (Johansen, Lavdas & Loomis 1981). These estimates are used to calculate fuel consumption which is a cornerstone of most fire intensity, fire effects and smoke management models.

Moisture content.--Live and dead fuel moisture are also major determinants of fire behavior. Yet their accurate prediction remains a goal in the South. Eventually the National Fire Danger Rating System (NFDRS) or Canadian Fire Weather Index (CFWI) equations should prpbably be adjusted to better reflect southern conditions. In the meantime, we have lent a degree of scientific backing to the time-honored "crackle test"[3] used by most southern woods burners (Johnson 1984a).A study is currently underway to assess the foliar moisture response of selected understory species on the Georgia Coastal Plain and Fiedmont to changes in soil moisture as measured by four commonly used drought indices, the objective being to relate changes in flammability to changes in these indices. Results of this study have been accepted for presentation at the Eighth National Conference on Fire and Forest Meteorology scheduled for April 1985 in Detroit.

National Fire Danger Rating System.--Several components and indices of the NFDRS, which most federal land management agencies are required to use, are designed to estimate the behavior of an initiating fire under given fuel and weather conditions. But most of these predictors are "notoriously unreliable throughout much of the southeast region" (Johnson 1980).[4] We attempted to evaluate NFDRS models C, 0, and P by comparing predicted fire behavior with observed data on archived fire reports. We hoped for a fair degree of correlation, but none was found. Our cooperator (Williams 1983) gave two reasons. First, he found a surpri.sing number of errors at all levels of input which he did not think were due to a lack of exposure to training. Rather, he blamed the observers preconceived notions that the NFDRS was not worth using. The second finding, which could not be conclusivel y shown in light of the first. was that the various indices and components needed to be normalized for southern conditions.

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[2] Data on file at Southern Forest Fire Laboratory.

[3] The estimation of fuel flammabil i ty by picking up a few upper litter layer needles or leaves and subjectively determining their tendency to snap or bend.

[4] Fire science adaptations for- Southern United States. Res. Work Unit Description (SE-2111),6p. On file, South. For. Fire Lab., Dry Branch, GA.

Future work. --If the NFDRS is to give meaningful results in the South, its indices and components will need to be adjusted for southern conditions because fire danger-fire behavior response curves do not agree with predicted values. Some, but certainly not all, of the NFDRS shortcomings can be corrected for in the BEHAVE system. For example, the live fuel moisture damping coefficient in this system does not fit southern conditions, nor does the systems response to passage of a cold front accompanied by significant rainfall. Regardless of the shortcomings of NFDRS components and indices, the possibility that they may nonetheless provide an acceptable analog of resource damage levels should be examined.

Another priority need is to field test and adjust Van Wagner's scorch equation (Van Wagner 1973) to fit southern conditions or develop a new model as necessary.

Effects Of Fire On Vegetation

Research under this general area is divided into site preparation, productivity or species composition.

Site preparation.--The use of fire in site preparation has received increasing attention during the last several years because of herbicide restrictions and mechanical treatment cost increases. Much of this attention has focused on smoke management; our RWU investigations in this area have been in response to user requests.

One cooperative study looked at burning rate and smoke production as a function of pile configuration. Following logging, many companies pile the remaining debris in windrows for disposal using fire. These windrows take many hours to burn and produce copious amounts of smoke that follow local nighttime air drainage patterns, often resulting in pockets of severely reduced visibility. Our field experiments showed that circular piles of logging debris burned much faster and produced smoke for a substantialiy shorter period than did windrowed slash (Johansen 1981).

Another cooperative study with industry assessed the value of very low intensity prescarification burns upon understory recovery and pine seedling survival and growth. Frequent summer showers can force postponement of these broadcast burns for weeks at a time, causing delays in subsequent tasks such as chopping and bedding and sometimes in the planting operation itself. Cognizant of the cost of these delays, forest managers often seize the first marginal burning day, accepting a patchy burn with little fuel consumption. Results from our investigations showed that after 6 years, these low-intensity fires had no significant effects on pine survival, growth, or overtopping (Wade and Wilhite 1981).

Organic soils occupy several million acres in Florida and coastal North Carolina. Surface fires such as site preparation bums can ignite this soil. Because of the tenacity of these fires, control is exceedingly time consuming so that emissions from these fires might impact an area for several weeks. Combustion products from these slow-moving, smoldering fires differ from those produced by flaming combustion. Futhermore, the high particulate emissions from these fires often combine with high nighttime humidities to form dense fog. The Southern Forest Fire Laboratory, in conjuction with the Florida Division of Forestry described the combustion characteristics and emissions from burning organic soils as a first step in addressing these problems (McMahon, Wade and Tsoukalas 1980).

Productivity.--We have several ongoing studies designed to assess southern pine survival and growth following various I evels of fire damage. The University of Florida has a cooperative study with us to look at needle moisture stress as a method of determining growth stress and to quantify the effects of growing space on tree recovery associated with various levels of crown scorch. Results are due this coming spring.

Results of a cooperative study with the Georgia Forestry Commission show a drastic immediate reduction in growth on trees with crown scorch approaching 100 percent. In fact, many of the 25-year-old trees put on virtually no radial spring or summer growth at breast height the year after this dormant season fire (Johansen 1984c). Besides the obvious economic ramifications of these results, they suggest other recently published findings (Waldrop and Van Lear 1984) showing no growth loss associated with high scorch,as determined by increment core analysis, failed to consider the possibility of missing rings.

Survival and growth of young loblolly pine plantations (1 to 8 years old) following dormant and early growing-season wildfires is being followed through a cooperative study with the South Carolina Commission of Forestry. Preliminary results have been accepted for presentation at the Eighth National Conference on Fire and Forest Meteorology scheduled for April 1985 in Detroit.

Results of the above three studies have several immediate uses. First, damage is quantified so its effects can be projected through to plantation harvest, allowing an economic analysis of replanting versus keeping the survivors. Second, the cost effectiveness of fire suppression expenditures can be addressed. These calculations can be used by fire control agencies to justify budget requests and as a basis for analyzing contemplated changes in current suppression tact ics.

Fire, however, is not universally detrimental to productivity. Studies have documented growth increases associated with nutrient cycling and understory competition control. These increases should be most noticeable in young pine stands. Although these stands are the most difficult to burn safely, the potential for a well-timed fire to reduce the fuel hazard while at the same time stimulating crop tree growth is appealing. Prescribed fire is not currently used in young plantations, however, because adequate guidelines do not exist. Young stands that have come through wildfire unharmed are occasionally found though, so we know it can happen. Another cooperative agreement with the Georgia Forestry Commission is aimed at establishing damage in young pine plantations associated with an array of prescribed burning cond it ions. One spin-off from our South Carolina wildfire damage study of value in this area is the cataloging of burning conditions on wildfires that did not cause excessive damage. There data may lead to prescription burn criteria for young stands.

Along this same vein, a cooperative study with Georgia Kraft is charting the understory recovery and pine growth after prescribed fires of two intensity levels applied to a 5-year-old loblolly pine stand on the Georgia Piedmont.

Community composition.--Students of fire ecology are well aware of the striking differences in plant and animal species composition associated with different levels of fire exclusion, but these differences have yet to be quantified in most cases. Our long-term winter burning plots in the palmetto-gallberry and mixed hardwood-shrub fuel types of the Atlantic Coastal Plain have recently been sampled to assess differences in terms of fuel management and plant succession after 24 years under selected burning cycles. We also have a cooperative agreement with Clemson University and the Forest Science Laboratory at Charleston, SC, to analyze the results of 35 years of burning the Santee fire plots in the mixed hardwood-shrub fuel type.

Although most of the above-mentioned studies have primarily benefited timber management, we have undertaken several studies that address the benefits of fire in managing other wild-land resource values. Three such cooperative studies are described below. The first, with the Piedmont National Wildlife Refuge, is set up to compare long-term species changes in composition associated with over 40 years of fire exclusion to those resulting from a 4-year prescribed fire cycle from a wildlife habitat standpoint. The second, with Clemson University, is designed to document the short-term effects of low-intensity fire on hardwood stem quality and on small mammal habitat in the Southern Appalachians. Another multifaceted cooperative study currently being prepared for publication demonstrated the ability of well-timed fires in Spartina marsh to temporarily halt shrub encroachment, to favor perpetuation of the target plant species, and to improve habitat for desired wildlife species, while simultaneously enhancing conditions for increased productivity of the aquatic food chain.

Miscellaneous Studies

Several studies were undertaken in response to daylighted user needs that do not neatly fit into the above categories.

South Florida's rapidly expanding population is concentrated on a narrow band along the coast, while the virtually uninhabited interior is comprised largely of a vast marsh (The Everglades) and swamp (Big Cypress). A large percentage of the human population is retired. Many of these people have respiratory ailments, while the ever-present tourists simply desire clear skies and sunshine. Extensive fires in the interior often coincide with periods of reduced visibility from haze along the southeast coast. Wade (1980) described an unsuccessful attempt to correlate high air-pollution days along this coast with fire activity in the interior.

A similar study was conducted on the 400,000-acre Okefenokee National Wildlife Refuge in extreme southeast Georgia. Johansen and Phernetton (1982) described the effectiveness of smoke management planning for prescription burns on the refuge in minimizing potential downwind smoke problems.

Most Southern States do not have a system for reporting prescribed burning activity within their boundaries, and those that do recognize the potential errors in the acreage figures collected. In an attempt to get a better estimate of the acreage prescribed burned by large landholders and the reasons for burning, Johansen and McNab (1982) surveyed selected large landholders in 11 Southern States. They concluded that over 2 million acres were prescribed burned by large landholders in 1975, of which over 500,000 acres were treated for site preparation.

The potential of prescribed fire to manage the hardwood forests of the Piedmont and Southern Appalachians is receiving renewed attention. Johnson (1982b) briefly reviewed the effects of fire in eastern broadleaf forests, and a cooperative agreement with Clemson (Van Lear and Johnson 1983) not only provided a review of fire effects, but also identified areas where additional. research was needed.

DISCUSSION

The information gained from these studies is forming the database needed to answer such far-reaching fire management questions as: How can prescribed fire costs be minimized while safely maximizing desired benefits? What are the economic tradeoffs between slow-moving backfires with little tree damage and faster moving headfires with more tree damage? What are the economic tradeoffs between interior plow lines and longer burn-out times? How much damage can be tolerated in young pine stands from hazard reduction bums?

Another end product of our research efforts will be a series of state-of-the-art publications outlining the role of fire in various southern ecosystems. Slash pine (Wade 1983), melaleuca (Wade 1981), and 10 South Florida ecosystems (Wade, Ewel and Eofstetter 1980) have already been addressed, while Johnson (1984b) covered the practice .of prescribed burning itself.

SUMMARY

The 27 research studies and the 21 publications to date accomplished under the auspices of the Fire Science RWU during its current 5-year charter represent a balanced attack on some of the more important unknowns associated with fire in the Southern United States.

With your continued help in research planning and study execution, the next 5 years will be even more productive.

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COMBUSTION PROCESSES IN WILDLAND FUELS
(A Research Progress Report 1980-1985)

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Abstract.--A 5-year summary of accomplishments, current activities, and planned actions for fire research project SE-2110 are presented. Areas of discussion center on: (1) characterization of wildland smoke, and (2) fuel, fire, and emission relationships, Characterization summaries include physical and chemical properties of smoke, smoke from burning pesticide-treated forest fuels, and smoke tracers.

Reducing smoke from smoldering combustion, understanding moisture relationships in forest fuels, and developing remote sensing methods for fire behavior and effects offer opportunities for the wildland fire manager to expand prescribed burning programs while minimizing detrimental environmental effects.

Additional keywords: Air quality; visibility; photo and video documentation; organic soil; image analysis.

INTRODUCTION

The Combustion Processes in Wildland Fuels Research Project (SE-2110) was established in 1980 following the phaseout of the Smoke Management Research and Development Program. The original title of the Project was changed from "Smoke Chemistry and Physics" to the current title to reflect expansion of our research from smoke characterization into several related areas of fire research. The words "combustion processes" were chosen to help convey the notion that our research would examine all phases of the wildland fire process, including smoldering combustion, a phase of the fire process often ignored in previous fire research efforts.

The Project's mission was described:

"To determine the chemical and physical characteristics of emissions from wildland fires, and to describe the mechanisms of formation permitting the use of source-related predictive equations for smoke management."

The work to be accomplished was initially divided into three broad problem statements:

Problem No. 1: Resource managers need information on the chemical and physical properties of forest fire smoke in order to be responsive to existing and emerging air quality legislation. (What is smoke?)

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Problem No. 2: Resource managers need information on atmospheric reactions of smoke in order to predict visibility impact at sites downwind from the fire source. (What is the fate of smoke in the environment?)

Problem No. 3: Functional relationships between flaming and smoldering processes, fire intensity, fuel characteristics, and emissions are needed in order to develop smoke management systems. (How can the process be modeled?)

Shortly after the Project was organized, we consolidated Problems 1 and 2 into a single problem entitled, "Characterization of Wildland Smoke is Needed." Consolidation was in response to the loss of several scientists and a sharply reduced operating budget.

This paper is intended as a summary of the Project's significant accomplishments, current activities, and planned actions. The literature cited are limited to recent related publications by Project personnel.

CHARACTERIZATION OF WILDLAND SMOKE IS NEEDED (Problems 1 and 2)

Many forest-land managers recognize that wildland productivity can be increased by the expanded use of prescribed burning. At the same time, they realize they must be able to develop methods to reduce or minimize the impact of smoke on air quality. As a first step, basic information is needed on smoke properties to defend the beneficial use of fire where burning regulations are being considered. This information will also provide the building block for developing predictive models for use in smoke reduction strategies and smoke management systems. Work on this combined problem was outlined in a problem analysis (McMahon and Tangren 1981) with the research divided into three components:

1. Chemical characteristics of smoke.

2. Physical characteristics of smoke.

3. Characterization methodology and instrumentation.

Chemical Characteristics of Smoke

Smoke from forest fires contains thousands of major, minor, and trace constituents. Our characterization research has been limited to constituents of national or regional significance. These include particulate matter, polycyclic organic matter, organic soil smoke, smoke from pesticide-treated forest fuels, and smoke tracers.

Smoke Particulate matter.--Particulate matter is the most important single category of emissions from forest fires. It is the major cause of visibility impairment and contains compounds known to affect human health. Total suspended particulate matter, or TSP, is that portion which is transported long distances in the atmosphere and has the greatest potential for environmental impact. Particles below 2 to 3 microns (fine particulates) have an especially long residence time in the atmosphere, contribute to smog formation, and penetrate deeply into the lungs. Effects of particulate matter are determined by three properties: size, sorption characteristics, and chemical composition. Interest in the properties of forest fire particulate matter was renewed in 1984 because of new efforts by the Environmental Protection Agency (EPA) to identify sources of visibility impact. In addition, EPA is in the process of proposing a new national standard for particulate matter for particles under 10μ in diameter (PM_{10}).

For years, particulate matter has been measured in units of mass determined by gravimetric analysis of the material collected on a glass fiber filter in a "hi-vol" sampler. In recent years, the chemical analysis of particulate matter, especially the organic fraction, has become a high-priority need for environmental and air pollution scientists because of possible effects on human health.

The organic fraction of TSP has traditionally been estimated by solvent extraction with benzene and reported as the "benzene soluble organics," or BSO. This fraction of ambient air TSP has been monitored for over 20 years. Many of the first characterization studies centered on the biologically active organic substances known collectively as Polycyclic Organic Matter (POM).

Polycyclic organic matter (POM).--Following publication of the Southern Forestry Smoke Management Guidebook in the late 1970's, one of the key characterization questions that remained concerned the magnitude of polycyclic organic matter (POM) emissions in wildland smoke. POM is a large class of chemicals released into the air as a result of incomplete combustion of carbonaceous fuels. Concerned about the cancer-causing potential of POM, EPA was collecting data on POM emissions and was considering ways to regulate sources that produced POM compounds. POM's from burning forest fuels were first reported by McMahon and Tsoukalas in 1978. Because of the regulatory potential surrounding this issue, high priority was given to continued study of these pollutants. Benzo(a)pyrene (BaP), one of the most studied POM compounds, was chosen for further study. Recently, White and others (1985) reported that the ratio of benzo(a)pyrene to particulate matter averaged 24 μg/g in four forest fuels common to the Southeastern States. Significant differences were not found between heading and backing fire types, but were among fuel types. Based on these data, a new national estimate for BaP production from prescribed burning was reported to be 11 metric tons annually. Earlier estimates were as high as 140 metric tons annually. POM studies continue in slash fuel types in cooperation with the Pacific Northwest Experiment Station. In addition, a comprehensive profile of organic chemicals in forestry smoke particulate matter is now being developed in cooperation with the USDA Tobacco Smoke Research Laboratory in Athens, Georgia. That work should be available for publication in late 1985.

At this time, it does not appear that wildland smoke management strategies will need to incorporate the complexities related to the POM compounds. Our current efforts, which focus on reducing smoldering combustion, should suffice to minimize total POM production.

It is worth noting here that in August 1984 EPA decided not to regulate POM as a class of compounds under the Clean Air Act "....until the agency had enough information to determine if regulation is appropriate...." According to current EPA figures, the major sources of POM are wood- and coal-burning stoves (44 percent); mobile sources such as automobiles, trucks, and aircraft (40 percent); forest fires (3 percent); fireplaces (3 percent); incinerators (3 percent); coke oven emissions (2 percent), and other sources (5 percent). It is clear, however, that small national percentages do not guarantee freedom from regulation. Coke oven emissions will soon be regulated under Section 112 of the Clean Air Act, and a standard for diesel emissions is in place. EPA is also considering other regulatory options for reducing POM emissions from wood stoves.

EPA is now in the process of reexamining the potential risk of POM emissions, source by source. Control technologies will be evaluated for their effectiveness in reducing emissions and health risks, and for their economic and social effects. Then, the agency may act to regulate additional specified sources of POM under the Clean Air Act.

Smoke from burning organic soil.--Organic soils cover many millions of hectares in the United States, including 2.8 million hectares in the Southern United States with about 1.0 million in south Florida. If these soils are sufficiently dry, they will support combustion when ignited by surface fires. Organic soils are generally consumed by smoldering fires that can last for months, burning down to the water table before going out. These slow-burning fires (horizontal rates of spread in the range of several meters per day) produce visible smoke when burning near the surface but can become remarkably smoke free as they burn through deeper layers. Combustion is evident from a general haze over the area combined with a disagreeable and pungent odor from partially oxidized organic material. These soils can, however, burn more rapidly and produce copious amounts of smoke around deep fissures in the soil or where the soil is overturned.

We began a study in the late seventies to learn more about the soil burning process. Field studies of soil burning would be very costly because the soil combustion rate is uncertain and it is difficult to collect representative emission samples. We decided to measure emissions from small blocks of burning soil in the laboratory. As reported by McMahon and others (1980, 1984) small blocks of organic soil collected in south-central Florida were burned and monitored at the Southern Forest Fire Laboratory. The soils sustained combustion for up to 4 days, even through layers containing 135 percent moisture. Peak temperatures were in the 400-600 $^{\circ}$C range. Particulate matter emission factors ranged from 1 to 63 g $\cdot$ kg^{-1}. The particulate matter was soot free and virtually all organic in nature (95 percent soluble in methylene chloride). The particulate matter was separated into neutral, strong acid, weak acid (phenolic) and basic fractions. The neutral fraction, which predominated (63 percent), was further separated into four subfractions. The subfractions containing polynuclear aromatic hydrocarbons (PAH) were purified by gel permeation chromatography and analyzed by gas chromatography. Percent distributions of various PAH ring systems were determined. Organic soil particulate matter was found to contain high percentages of methyl and polymethyl PAH's in the three-and four-ring PAH systems. For 13 samples, the benzo(a)pyrene emission factor averaged 213 μg kg^{-1} with a range between 9 and 785 μg kg^{-1}. Emission factors for carbon monoxide (269 $\pm$ 135 g kg^{-1}), nitrogen oxides (1.7 ± 1.8 g kg^{-1}), and total hydrocarbons (23 ± 15 g kg^{-1}) as methane were also reported.

Smoke from burning pesticide-treated forest fuels.--Since 1982, we have carried out three smoke-related research studies as part of the National Agricultural Pesticide Impact Assessment Program (NAPIAP): (1) pesticides released from burning treated wood, (2) release of copper, chromium, and arsenic (CCA) from the burning of wood treated with preservative, and (3) release of herbicides from the burning of treated under-story forest fuels.

(1) Pesticides released from burning treated wood.--Rapidly rising energy costs have created a large demand for alternative energy sources in home heating. Many households have turned to wood as a primary or supplemental energy source because of the abundance of this fuel in many parts of the country. A common source of this firewood is hardwood stems killed by herbicides or wood that has been sprayed following a beetle attack. Recently, there have been numerous inquiries from the public regarding the safety of burning pesticide-treated wood in home fireplaces or stoves.

A novel combustion tube furnace technique (Fig. 1) was developed to simulate the wide range of thermal conditions possible in wood stoves and fireplaces. A range of conditions from slow smoldering combustion to rapid flaming oxidation was applied to wood samples treated with seven pesticides. The implications of the study as reported by Clements and others (1984) are:

". ..Pesticide treated wood will release substantial amounts of pesticides when the sample is heated slowly. This can occur in damped wood stoves as well as stove and fireplace fires that are not fully developed ."

". . .The amount of pesticide released will depend on the physical and thermal properties of the compound. Relatively stable compounds such as Lindane and Dicamba as well as compounds with significant vapor pressures can be expected to be released (distilled) in significant amounts when the wood is heated slowly."

". ..Under conditions of rapid flaming combustion, most pesticides decompose readily, with higher temperatures causing complete decomposition. With a well-ventilated fully developed fire in a wood stove or fireplace (where temperature can reach 800-1000°C), one can expect complete decomposition of most common pesticides."

"...Because of the uncertainty of ventilation and temperature in many domestic wood-burning devices, a safe-side approach to the use of pesticide treated wood is well advised. Thus, the indoor storage and burning of pesticide treated wood is not recommended unless it has been predetermined to have decomposed or removed from the wood by aging and weathering processes ."

(2) Release of copper, chromium, and arsenic (CCA) from the burning of wood treated with preservative.--Chemicals have been used to protect wood from insect and water damage for many years. One of the

more common formulations contains copper, chromium, and arsenic salts and is referred to as chromated copper arsenate or CCA. Public concern has been raised over the possible release of highly toxic smoke when CCA wood scraps are burned. The levels of CCA released when wood is burned under different combustion conditions is not known. This study has two primary objectives:

a. To determine the percent of total copper, chromium, and arsenic released to the atmosphere when CCA-treated wood is burned under various combustion conditions.

b. To determine on selected samples the nature of the arsenical chemicals released to the atmosphere.

In this laboratory study, CCA-treated wood is being burned under controlled conditions (time/temperature) in a combustion tube furnace. To date, experiments have been run at 400°C and 800°C. An average of 17 percent of the arsenic is released at 400°C, while a range of 19 to 31 percent is released at 800°C (depending on exposure time). Arsenic speciation and additional experiments at 1000°C are planned. Results will be reported at the National Air Pollution Control Association Conference in June 1985.

(3) Release of herbicides from the burning of treated understory forest fuels.--Concern has been raised about the possible impact on air quality from the popular "brown and burn" method of controlling unwanted vegetation in forests. In this method, herbicides are applied to the vegetation, and a few weeks later--after the leaves are brown--the area is burned by prescription. The concern centers on the possible harmful amounts of parent herbicides and their thermal decomposition products that may be released to the atmosphere during burning.

A study is underway to quantify emissions of parent herbicides as a function of fire type and to identify the major herbicide thermal decomposition products produced under these conditions. A worst case application of a Tordon mixture (2,4-D and Picloram) was applied to pine needle litter and burned under controlled conditions in the combustion laboratory at the Southern Forest Fire Laboratory (Fig. 2).

Results to date (Clements and others 1984b) indicate that a very high percentage of Tordon components will thermally decompose when sprayed on a fine forest fuel and then burned. Picloram decomposed (>99 percent) in all fires. 2,4-D decomposed (>99 percent) in the simulated backing fires, but was released in small amounts (4.8 percent) in the simulated heading fires.

The amounts of herbicides released or decomposed in this experiment cannot be extrapolated to other herbicides that have different chemical and physical properties. Also, some decomposition products are known to be hazardous. However, it is clear that burning techniques that cause flaming to dominate not only favor pesticide thermal decomposition but will also enhance the convective lift and rapid dilution of the smoke away from the burn site.

Forestry smoke tracers.--A logical development emerging from smoke characterization studies is the identification of a unique chemical fingerprint or signature for forest fire emissions which could be used for plume tracking, visibility studies, and source apportionment. Until recently, source-oriented dispersion models and subjective visual estimates from aircraft have been the primary means by which air-quality specialists have determined the impact of a smoke plume at a receptor site. These methods have been approximations at best, with most dispersion models accurate only within a factor of two. Because of this limitation, there has been increasing interest in receptor model technology; that is, models that assess and separate the individual contributions from mixed pollution sources. Receptor methods have become feasible because of recent improvements in the sampling and analysis of aerosols. Receptor models start with the measurement of a specific feature of the aerosol at the impacted site (receptor). They then calculate the contribution of a specific source type based on a morphological or chemical signature of the source.

Several receptor techniques are being developed to assess the environmental impact of wood stove and fireplace emissions; they could also prove useful as forestry smoke tracers (McMahon 1983). Atmospheric scientists are also mapping the tropospheric distribution of trace gases from biomass burning; their results should prove helpful in finding a forestry smoke tracer. Ward and others (1982) reported emission factors for trace sulfur species released from five forest fuels burned in the laboratory.

Receptor models are very new and still an emerging technology. At present, methods often only provide qualitative information. However, with expected advances in sampling and analysis methods, these techniques could become the primary diagnostic and predictive tool used in air resource management. Perhaps the greatest opportunity for improving receptor models lies in the area of detailed analysis of organic emissions. Most of the models up to now have concentrated on elemental fingerprints. At present, there are no reliable elemental signatures for many combustion sources. Elemental analysis is relatively simple and inexpensive when compared to the techniques needed for organic analysis. However, advances in organic sampling and analysis, which can be expected, may provide the opportunity for finding compounds or ratios of compounds that will distinguish between two closely related sources. Approaches should consider the type of organic matrix present in the fuels and then focus on expected pyrolysis and combustion products. For forest fuels, specific aldehydes, furans, phenols, or terpenes would be a place to start. Organic group, class, or functional group analysis may also be appropriate, as well as individual constituent analysis, or a combination of both.

Physical Characteristics of Smoke

The physical characteristics of smoke are important because of their effects on smoke dispersion patterns, human health, and visibility (McMahon 1981). Particle size, particle shape, absorptive properties, density and refractive index all contribute to the reduction of visibility by smoke. Many of these characteristics are also important in describing human health effects. Inhalation and lung retention are directly dependent on particle size. Particles below 2.0 microns penetrate deepest into lungs and cause the greatest concern. In addition, particle surface properties may cause additional chemical species to be absorbed and carried to the lungs. Particle size and aerodynamic characteristics determine the drift pattern of particles and their residence time in the atmosphere. Fine particles (below 2.0 micron diameter) generally behave as a gas and can remain dispersed in the air for weeks and months.

Smoke particle size.--Some early reports on the size of forestry smoke particulate matter erroneously indicated a particle size range from 50 to 100 μm in diameter based on examination of microscopic slides placed downwind from the fire. The particles examined were primarily partially consumed fuel fragments and ash particles. These large particles are produced primarily by high-intensity fires when the turbulent convective activity in the fire zone is sufficient to mechanically generate and entrain large particles in the smoke column. In most cases, they drop out near the fire and are not found in forestry smoke plumes at great distances from fires. A number of studies reviewed by McMahon (1983) have now shown that most of the particles formed in forest fires are of submicron size, typical of a combustion aerosol. These studies generally agree on an average particle diameter between 0.1 and 0.5 μm, for mass, number, or volume distributions.

Visibility relationshins.--The effect of smoke on visibility depends not only on the concentration of particles emitted, but on the optical properties of the particles as they affect the scattering, absorption, and total extinction of light. A number of studies have reported the relationship between the mass of forest fire particulate matter and light scattering properties. Comparison of data is hampered by the use of instruments with different spectral reponses and/or by different methods of analysis. Tangren (1982) has recently reviewed this topic and recommends a backscatter ratio of 2.8×10^5 for smoke plumes on the ground near the fire and 2.0×10^5 for airborne measurements of aged smoke downwind from the fire. From a smoke management perspective, these new values reduce some of the error in making visibility predictions down range from a burn.

The color of forest fire smoke can vary from dark black, through various shades of grey, to pure white. Black smoke will predominate during vigorous flaming combustion, especially when burning foliage fuels containing a high percentage of extractable hydrocarbons. As flaming combustion diminishes, tarry droplets from smoldering combustion begin to predominate and the smoke color changes from black to white. On a volume, number, and mass basis, the tarry droplets usually predominate over the solid black soot particles. Soot particles scatter as well as absorb light. This double effect gives soot particles an influence on visibility greater than their atmospheric concentration alone would suggest. Also, the soot particles, although chemically inert, carry on their surface reactive groups that take part in important atmospheric reactions. Recently, the absorption properties of smokes from laboratory fires that represent prescription burns in the Southern States were quantified by Patterson and McMahon (1984). Measured optical properties and previously measured size data were used to determine the overall radiative properties for the smokes from these fires. As expected, results showed significant differences in absorption of the smoke emissions between flaming and smoldering combustion, with specific absorption coefficient B_a values from 0.04 to 1.0 $m^2 g^{-1}$ at 632.8 nm. These data indicate that under conditions of flaming combustion approximately 50 percent of light extinction will be due to particulate matter absorption, while under purely smoldering conditions, only 5 percent of light extinction will be due to absorption. This information is providing a means of discriminating forest fire visibility effects based on type of burning and fuel characteristics. It is also serving the needs of researchers attempting to model the effects of forest fires on global climatology, carbon cycling, and mass fire behavior (Fatterson and McMahon 1985).

Characterization Methodology And Instrumentation

Many of the procedures and much of the equipment associated with the study of air pollution and atmospheric chemistry are relatively new. As a result, most studies undertaken by the project required the development and/or validation of instruments and procedures unique to smoke monitoring and evaluation. Some recent examples are:

A micromethod for benzo(a)nvrene.--A simple and rapid method employing a high-pressure liquid chromatographic technique has been developed and validated for determining benzo(a)pyrene concentrations in particulate matter from prescribed burning (White 1985). The procedure is being used in studies in the Southeast as well as in cooperative work with the Pacific Northwest Experiment Station.

A microcombustion method applied to forest fuels.--This method requires thermogravimetric (TG) instrumentation and small (10 mg) samples of ground-up forest fuels (Fig. 3). An average of 95 percent of the combustion products released as particulate matter, volatile organic carbon, total hydrocarbons, carbon monoxide , and carbon dioxide are accounted for. The method best simulates slow smoldering combustion and oxygen-starved pyrolytic conditions of fuel decomposition (Clements and McMahon 1984). The TG system was used to determine the amount of nitrogen oxides produced from burning 12 forest. fuels that varied widely in nitrogen content (Clements and McMahon 1980). Results indicate that approximately 25 percent of the fuel nitrogen is converted to nitrogen oxides when the fuels burned below 1000°C.

Smoke monitoring systems.--A sampling concept originally developed for use with a balloon system for monitoring forestry smoke plumes (Ryan and others 1979) has been modified and used in many new applications. The original system was portable (2.3 kg) and consisted of: a temperature and windspeed monitor, a particulate matter sampler, and a gas grab-sampler. The system was designed to make use of the "carbon-balance" procedure for obtaining fuel consumption data. In the past, fuel consumption was often determined by tedious before-and-after "lift & weigh" techniques. The carbon balance method chemically balances the fuel's known carbon content with the carbon content of the measured combustion products . This technique was summarized and evaluated by Nelson (1981) and has proven to be crucial to the monitoring of forest fires where traditional lift-and-weigh techniques are not possible. The system was applied by Ward and others (1980) using a tower-based vertical array in burning studies of southeastern understory fuels. Upon transfer to the Pacific Northwest Station, Ward further modified the system to operate on a real-time basis in a horizontal configuration over broadcast fuels. Portable versions of the system are evolving (Fig. 4) and have been used by White (1984) for monitoring benzo(a)pyrene/particulate matter ratios and by McMahon (1982) for monitoring emission from piled forest residues mixed with organic soil. This latter experiment also demonstrated the feasibility of using a platform monitoring system and a modified tepee burner to monitor emissions and combustion rate from large-scale (>500 kg) burning experiments (Fig. 5 and 6).

FUEL, FIRE, AND EMISSIONS RELATIONSHIPS ARE NEEDED (Problem # 3)

Smoke reduction and management cannot be achieved simply by a chemical and physical characterization of emissions. There is also a need to understand how fuel characteristics and fire behavior are related to the amount and type of combustion products. This information can then be used to develop burning prescriptions that will assist in predicting and minimizing smoke production.

Initially, the activities for this problem (under the leadership of Darold Ward) focused on studies which would lead to particulate matter emission models that extended the utility of the Southern Forestry Smoke Management Guidebook. As a first step, Nelson and Ward (1980) described a relationship between particulate matter emission factors[2] (EF_p) and Byram's fireline intensity[3] (I) for backfires in southern fuels (Fig. 7). Emission factors were predicted by the expression

$$EF_p = 60.8I^{-0.313} \qquad (1)$$

for fires with I between 20 and 300 kw m^{-1}.

An extension of that work was published by Ward and others (1980) to include a relationship between EF_p and I for head fires in the palmetto-gallberry fuel type with fireline intensities up to 1750 kw m^{-1} (Fig. 8). A parabolic model fit the data below 500 kw m with

$$EF_p = 19.5 - 0.07371 + 0.000145I^2. \qquad (2)$$

For a fireline intensity range from 500 to 1750 kw m^{-1}, the equation that best fits the data is

$$EF_p = 16.7 + 0.0002431. \qquad (3)$$

It follows from the above equations that particulate matter production can be minimized for prescribed fires in the palmetto-gallberry fuel type by fire management techniques which keep fireline intensity between 200 and 300 kw^{-1}.

A further extension of this work was reported by Ward (1983), who

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[2] Emission factor (EF) defined as mass of particulate matter produced per unit mass of fuel consumed, expressed as grams per kilogram g kg^{-1} or the English equivalent lb ton^{-1}.

[3] Fireline intensity (I) is expressed as kilowatts per meter (kw m^{-1}) or the English equivalent BTU sec^{-1} ft^{-1}.

proposed a method for estimating particulate matter emission rates[4] using flame length as the independent variable. Flame length tends to integrate those factors affecting smoke production for fire conditions where flaming combustion dominates and smoldering does not persist for longer than 30 minutes.

Given an emission rate model, a forest manager can apply a number of fire management techniques to burn under conditions that accomplish burning objectives while minimizing the adverse environmental effects caused by smoke production. The model can also be used in conjunction with the Southern Forestry Smoke Management Guidebook to predict smoke concentrations downwind from the source.

The draft problem analysis prepared in 1980 to guide the work in Problem 3 gave emphasis and priority to modeling emissions from burning forest residues. Shortly afterwards, D. Ward was transferred to the Pacific Northwest Station to address the urgent needs in that region for smoke management. Emphasis and priority were given to reducing emissions from the broadcast burning of forest residues in the Pacific Northwest.

With the loss of a key scientist and the need to minimize any duplication of effort, we revised our Problem 3 problem analysis. The new analysis was approved in June 1983 and given the title, "Fuel, Fire, and Emissions Relationships in Wildland Combustion Processes are Inadequately Described" (McMahon and others 1983). We focused on three broad problem areas:

1. Reducing smoldering combustion in southeastern fuel types.

2. Moisture relationships in dead forest fuels.

3. Developing remote-sensing methods for fire behavior and fire effects applications.

Smoldering Combustion

The progress made in recent years in describing smoke from various types of forest fuels has provided much needed information on smoke properties, fuel, and emissions. The early research efforts were geared at filling major voids needed to rapidly produce a state of knowledge guidebook (Southern Forestry Smoke Management Guidebook 1976) and a national EPA source assessment document (Chi and others 1979). Very little research was aimed at providing cause and effect relationships among fuel, fire, and emission characteristics. Earlier fire research dating back to the 1940's did develop some fuel and fire relationships; but the emissions component of the process was largely ignored because air quality was not a major issue and air resource management was not a well-established concept. In those days, fire research was aimed at

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4 Emission rate (ER) is defined as the rate of production of emissions per unit length of fireline expressed as micrograms per meter per second or the English equivalent pounds per foot per second.

providing a better understanding of fire danger, fire occurrence, fire suppression, and fire behavior. Research objectives and methodology dealt primarily with the flaming or active phase of the combustion process. The smoldering phase did not receive much attention because it was not perceived to be related to operational needs. In effect, when smoldering combustion commenced, most fire problems ceased. Ironically, it has become increasingly evident that one of the most serious smoke problems in the South is associated with the smoldering stage of the combustion process. During this stage of combustion, the fire is often judged to be out, but smoke continues to be produced by smoldering snags, logs, stumps, or organic soil. Local visibility can be seriously impaired; property is damaged or lives lost because of smoke transport into sensitive areas (especially toward the end of the day). This smoke effect is similar to the one described in the Southern Forestry Smoke Management Guidebook during the no-convective-lift phase[5] of combustion. The smoke is produced during the smoldering combustion of ground fuels which actually carry the fire. Due to the low rate of heat release in this phase, the smoke tends to stay near the ground, creating smoke problems in the local area.

The research question posed by this problem component is: How are fuel characteristics and fire behavior related to smoldering combustion? The operational question is: How can the smoke impact from smoldering combustion be predicted and minimized? These considerations raise more specific questions on how live fuels, duff moisture, and moisture gradients in the fuel layer affect the smoldering component in spreading fires. For fires in piled or windrowed fuels, the relationship of fuel particle size, fuel bed porosity, and fuel bed arrangement to duration of smoldering combustion remains unknown.

There is little doubt that smoke production and smoldering potential are strongly affected by fire behavior and firing techniques; however, quantitative relationships are lacking for most fuel and fire types. From an operational perspective, a land manager may have a choice of a heading, backing, or strip-head fire in a given situation. It would help if he knew in advance which technique would minimize smoldering combustion and to what degree. Knowing in advance when smoldering combustion might be a problem introduces new options in scheduling and planning prescribed burning.

Information from studies dealing with effects of fuel characteristics and fire behavior can be applied directly to update prescribed burning guidelines, and to improve techniques of writing smoke management plans. In addition, data originating from these studies can be used to strengthen models of fuel complexes, fuel moisture, and fire behavior now used to make management decisions.

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[5] The convective-lift phase of combustion occurs when most of the emissions are entrained into a definite convection column caused by rapid release and ascent of heat during combustion. The no-convective-lift phase of combustion occurs when no well-defined convection column is present and entrainment of emissions is small.

In order to broaden the range of studies in support of this research, the Southern Forest Fire Laboratory combustion room and wind tunnel facility was renovated in 1983. In addition, some field studies will be conducted using the large outdoor platform described earlier (Fig. 6).

Moisture Relationships in Dead Forest Fuels

Moisture content of dead forest fuels is obviously an important factor determining forest fire burning rates and products of combustion. It is also one of the few combustion-related parameters that land managers can control or factor into their prescribed burning decisions. Although the effect of fue' moisture on rates of fuel consumption and energy release is generally understood, the corresponding effect on composition of the smoke is not well known. It is believed that increasing amounts of live fuel in the burning material are associated with increases in particulate matter (or smoke) production per unit mass of consumed fuel since reduced energy release is expected to lead to less efficient combustion. A similar effect is expected when dead fuels at high moisture contents are added. However, these effects have not been demonstrated with carefully controlled experiments.

This discussion is limited to information gaps and needed studies of fuel moisture in dead fuels. Fire behavior models and the National Fire Danger Rating System (NFDRS) attempt to predict effects of dead fuel moisture content. Both user and research personnel have suggested that the NFDRS generally overestimates the drying rates of southern fuels, thus causing an overestimation of fire danger.

Further work on forest fuel moisture relationships is needed. One problem in the NFDRS is that its derivation is based primarily on moisture relationships and drying rates of wood. In many areas, especially in the South, a fire's growth is determined by its spread through a layer of pine needles, grasses, and other plants on the forest floor. Information on these fuels, as well as wood, should form the basis for modeling fire behavior and moisture changes in southern fuels.

Understanding moisture relationships in forest fuels and describing them quantitatively can be divided into three researchable areas:

1. Equilibrium relationships.

2. Rates of moisture loss.

3. Effects of cycling and infiltration.

Equilibrium relationships.--Equilibrium moisture contents are determined by relative humidity, ambient temperature, and sorption history. The research needs can be subdivided into four categories: isotherm characterization, weathering effects, hysteresis effects, and fuel classification.

(1) Isotherm characterization.--The graph of moisture content of wood or forest fuel in equilibrium with various relative humidities at constant temperature is referred to as a sorption isotherm. Most of the practical work on sorption isotherm characterization has been done for wood and textiles. The model

currently used by most researchers to describe equilibrium forest fuel moisture requires evaluation of five parameters. A model proposed recently by Nelson (1983) uses only two parameters and is mathematically simple. It applies over a relative humidity range from about 5 to 90 percent, and has accurately correlated sorption data for wood and cotton. Its applicability to forest fuel sorption was recently described by Nelson (1984), who applied the model to five sets of sorption data in the literature to illustrate goodness of fit (Fig. 9).

The effect of temperature on equilibrium moisture content has not been extensively studied. A sorption model should be selected and temperature dependence of the parameters studied to resolve questions concerning the temperature effect. This effect is important in equilibrium relationships and in description of the drying process.

(2) Weathering effects. --The effect of weathering of fuels on moisture equilibrium is unclear. Generally, weathering increases the moisture content unless the material lost in weathering is more hygroscopic than the remaining material. There is a need to determine the extent to which sorption isotherms for southern fuels are affected by weathering and to what extent this process determines moisture exchange and retention characteristics.

(3) Hysteresis effects. --Sorption measurements in cellulosic materials are complicated because the amount.of water held at equilibrium is determined by the direction from which equilibrium is approached. This hysteresis effect has been studied carefully by wood and textile researchers. The significance of hysteresis in forest fuel moisture relationships is not clear because the magnitude of the effect is not known. Studies of the magnitude and variation in the hysteresis ratio will provide useful information about equilibrium moisture values.

(4) Fuel classification. --Though many fuel types exist on the forest floor, it may be possible to subdivide them into three or four classes in terms of their sorption properties at a constant relative humidity to account for small differences due to species. There is a need to examine the possibilities for combining species, or mixtures of species, into classes according to the values of their sorption isotherm parameters.

In 1983, we began a small-scale laboratory experiment to study the sorption of water in wood and fine forest fuels under controlled conditions of humidity and temperature. Equilibrium moisture contents have been completed for four southern fuels exposed to varying relative humidities at 80 °F. Measurements at 95 °F are underway, with additional runs at 65 °F and 50 °F to follow during the winter of 1985.

Rates of moisture loss. --Classical diffusion theory forms the basis for predicting drying rates in processed wood and textiles, as well as forest fuels. The theory, in its most common form, utilizes a constant drying rate coefficient, whereas numerous experiments on wood, textiles, and forest fuels have shown that these coefficients are dependent on the state of the fuel and environmental variables.

Experimental observations of forest fuel drying have been more extensive than theoretical work, but both approaches are needed for studies in this problem component. A significant gap in current understanding of moisture exchange in forest fuels is the form of the gradient that drives moisture diffusion in fuels both above or below the fiber saturation point. Our research plans in this area can be subdivided into three categories--basic mechanisms, surface effects, and model development.

Theoretical work on mechanisms of moisture movement in wood begun in 1982 is rapidly nearing completion, and three manuscripts are in press (Nelson 1985, 1985b, 1985c). The first two papers identify the driving force for bound water diffusion and describe a model of diffusion under isothermal conditions. The third paper confirms the ability of thermodynamic equations to describe moisture changes in wood under nonisothermal conditions and discusses a model for calculating rates of change. The results of this work will apply to similar processes in forest fuel particles. A summary of this work was presented by Nelson (1984b) at a recent North American Wood Drying Symposium.

Effects of cycling and infiltration.--Studies of sorption and drying under constant environmental conditions are only preliminary work upon which to build more realistic moisture predictions under field conditions. Our theoretical and laboratory studies just described apply primarily to a "drying phase," but here our interest is centered on a "wetting phase" due to precipitation and to diurnal fluctuations of temperature, solar radiation, relative humidity, and windspeed. Our research plans for this area have been subdivided as follows: diurnal cycling, interception of rainfall by litter, and development of a final model to predict rates of moisture gain and loss. We will begin studies in this area in 1985.

Developing Remote-Sensing Methods for Fire Behavior and Fire Effects Applications

Over the years, research has provided several operational guidelines on how to quantify fire behavior and fire effects. Unfortunately, the research database is often narrow while the operational applications are broad; as a result, models don't seem to fit in specific cases. In prescribed burning and in control of wildfires, personnel are often required to make subjective estimates of phenomena that are difficult to define and measure (e.g. flame length and tree scorch).

This component of the problem analysis is aimed at developing objective and quantitative methods for measuring fire behavior and effects through the use of low-cost photo and video techniques. In the process, we hope to broaden and strengthen the research database for some of the models that apply to fire behavior and fire effects.

Fire behavior applications.--Estimated flame length is one of the most widely used descriptors of fire behavior. Recent experiences at our laboratory indicate that 50 percent error can occur between an observer estimate and an accurate photographic measurement. Furthermore, in operational fires, flame length as currently defined (distance from flame tip through the center of the flame to the fuel surface) is often obscured by a curtain of flame surrounding the elliptical-shaped fire fronts. Better methods for measuring fire behavior are needed using flame geometry techniques as suggested by Nelson (1980). Photographic measurements of flame length offer the opportunity to replace subjective estimates with objective quantitative appraisals that can be documented and retrieved for later reexamination (Adkins and others 1976; Clements and others 1983).

Portable video cameras and recorders show potential as an improvement over photographic methods for fire behavior research both in technical features and for a fraction of the cost. Advances in image tube technology produce well-defined images of flame, and camera-recorder systems have integral calendar-clock annotation. An approximate cost comparison based on running time for continuous operation between video and 16-mm film is--film $6.90/min. versus $.12/min. for video tape. Once the photo or video image is acquired, computer-based image analysis systems can be employed for rapid data reduction and analysis (Fig. 10).

In 1983, a study was initiated in the recently renovated Fire Lab wind tunnel (Fig. 11) to examine video images of flame geometry as useful descriptors of fire intensity. Results should provide fire researchers with a low-cost, objective method for quantifying fire behavior. Further development should yield a system with low-cost operational utility.

Fire effects applications.--The inability to easily and accurately measure flame length and/or fire intensity has hampered fire researchers from fully describing the effects of fire on forest and range ecosystems. Although numerous studies have been conducted to determine the relationship of fire intensity to fire effects, many investigators are forced to use subjective estimates of fire behavior and tedious, labor-intensive methods for describing fire effects. In some cases, the ecosystem reponses to fire are reported without any descriptive, quantitative statement of fire treatment level or fire intensity. Promoting the use of prescribed fire will be difficult without developing more economical and accurate methods for measuring fire effects. Aerial photography, combined with computer-based image analysis, should help to solve this problem.

Determining the effects of prescri.bed fire treatment on living trees is one of the more important objectives of fire research and forest management. Present methods such as line transect sampling of crown scorch height for fire intensity are highly subjective. Prescribed fire effects can range from enhanced growth and yield to various degrees of scorch, leading to reduced growth rate or, in severe scorching, total tree kill. Quantifying tree scorch and other fire effects in forest stands is complex because of the number of variables that need to be considered. Site factors such as soil type, drainage, accumulation of understory fuels, fire history, and age of stand al 1 enter into the ability of trees to withstand fire. Determining how these factors affect a site before and after a treatment with prescribed fire is necessary if the net effects from that fire on the forest are to be isolated and evaluated. In the past, age of stand and age of rough were usually provided as descriptors of site conditions prior to a prescribed fire. This information may not be adequate in describing site conditions prior to burning and, consequently, the effect of various fire intensities. Questions concerning the preburn and afterburn conditions of forest stands continue to shadow results from prescribed fire treatment because no practical quantitative method exists for determining forest stand conditions that integrate all site factors and fire effects.

Measurements of increases in tree diameter and height to determine effects of fire on growth are expensive and highly variable, considering the manpower and time required to sample even a small portion of one experimental field fire. Aerial color infrared (CIR) photography combined with computer-based image analysis offers a possible solution to problems with characterizing forest sites and determining the fire effects. The ability of aerial CIR photography to contrast diseased, stressed farm crops and trees that otherwise are invisible to humans is well documented. Physical changes to plants and foliage that are caused by disease affect their reflectivity of the electromagnetic spectrum. Differences in color are easily distinguished visually in the advanced stages of infection, but the reflectivity in the near infrared of material from a stressed plant or tree is altered dramatically and can be detected before the stress becomes visually apparent using a film that is sensitive to that band of electromagnetic radiation. Gther conditions of the forest, such as time of year, age of stand, differences between sites, and moisture content of leaves and needles, also affect infrared reflectivity. Since CIR film can detect these differences, it may be possible to better define conditions of sites prior to experimental burns so that the effects of the fire can be isolated from other site stresses. Heat effects from prescribed fires and wildfires may affect the near infrared reflectivity of foliage and plants. The variation in reflectivity of a subject can be measured from photographic film both for color and density. If varying intensities of heat applied to tree crowns affect the infrared reflectivity proportionally to the amount of heat received, then by measuring this difference on the film, the heat effect can be quantified. Comparing film density readings with ground measurements of crown scorch would be required to calibrate this method as a remote sensing technique.

Before any field efforts to test this concept are initiated, we plan to conduct a laboratory experiment with a controlled heat laboratory furnace to test changes in infrared reflectivity of live fuel samples as affected by known quantities of heat. This preliminary work should begin in 1985.

TECHNOLOGY TRANSFER

Our Project's accomplishments are being applied at the regional and national level. Research users include fire scientists conducting prescribed burning research and earth scientists studying the effects of fire and smoke on atmospheric chemistry and climate. Operational users include: federal land managers responsible for air resources and federal and state personnel involved in smoke management, prescribed fire, and fire management planning. Some recent technology transfer activities include:

1. May 1982 and March 1983. Forestry smoke characteristics and their impact on air quality were presented at a prescribed fire management course to Forest Service and other land management personnel at the National Advanced Resource Technology Center at Marana, Arizona.

2. June 1983. A session on forest fire emissions was presented to a national air-quality audience at the Air Pollution Control Association Annual Conference.

3. January 1984. Smoke characteristics and management lectures were presented at the USFS Region 8 Prescribed Fire and Smoke Management Workshop.

4. 1984. Provided chapter material for the National Smoke Management Guidebook under the sponsorship of the National Wildfire Coordinating Group.

5. 1985. A video tape program about smoke characteristics and smoke monitoring were presented to an interagency audience at the Smoke Management Workshop, Marana, Arizona, and nine regional locations.

CONCLUSIONS

If wildland fire managers are to expand prescribed burning programs while minimizing detrimental environmental effects, they will need improved understanding that only research can provide. Research can help to reduce smoke from smoldering combustion, it can determine moisture relationships in forest fuels, and it can develop remote sensing methods for fire behavior and effects.

The art of smoke management, begun in the Southeast in the 1970's, has evolved into the science of smoke management. At local, regional and national levels, wildland managers have developed partnerships with air-quality specialists resulting in reasonable guidelines instead of harsh regulations. We must sustain our progress by continuing to accept our new role as air resource managers and by incorporating smoke management guidelines into our prescribed burning programs. In addition, we must be prepared to address new national regulations dealing with small particles and visibility standards. Even more compelling is the need to find ways to reduce smoke-caused accidents on highways which crisscross the prescribed burning network in the South.

The tools for smoke management are building blocks of knowledge which deal with fuel, fire, emission, and weather variables. Although some information is already available, much remains to be accomplished if we are to greatly expand the use of prescribed burning in the South. In the years ahead, the Southern Forest Fire Laboratory will continue to provide the leadership in developing new tools for prescribed burning and smoke management.

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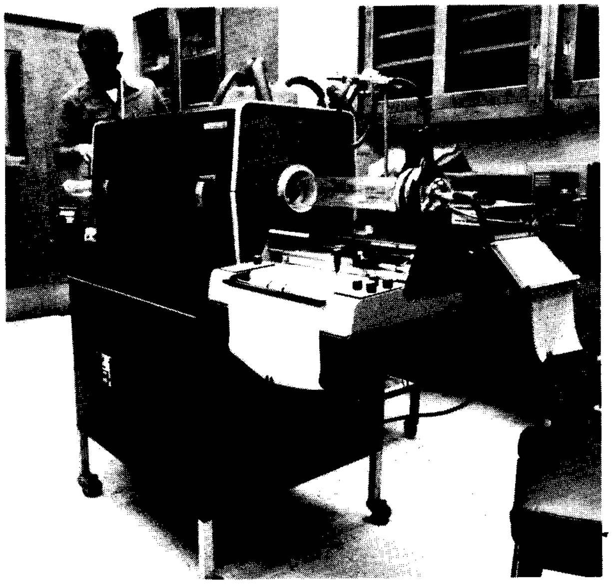

Figure 1.--A combustion tube furnance. Temperature, flow rate, and composition of combustion gases can be controlled by the operator.

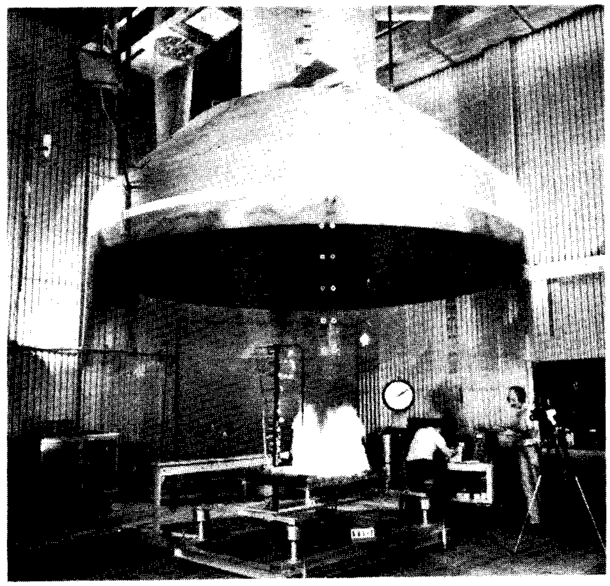

Figure 2.--Southern Forest Fire Laboratory Combustion Room. Slope of burn table can be adjusted to alter burning conditions.

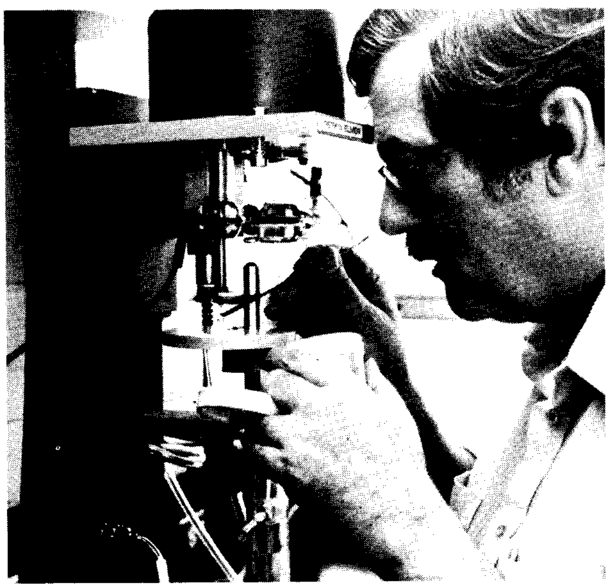

Figure 3.--A Thermogravimetric System is a useful microcombustion apparatus. The balance pan is being loaded with a fuel sample.

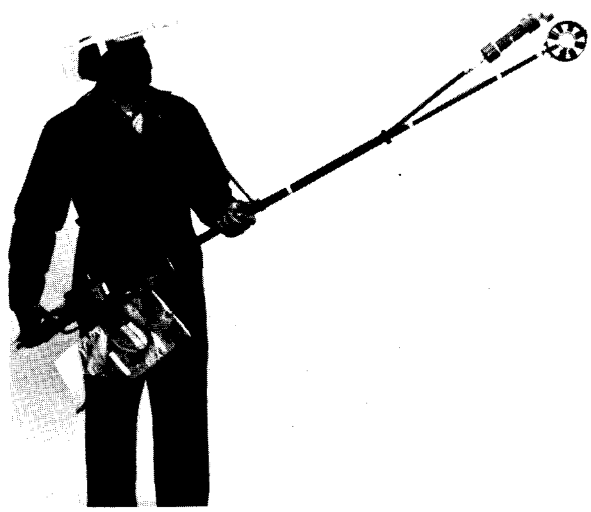

Figure 4.--Portable sampler for monitoring emissions from burning forest fuels.

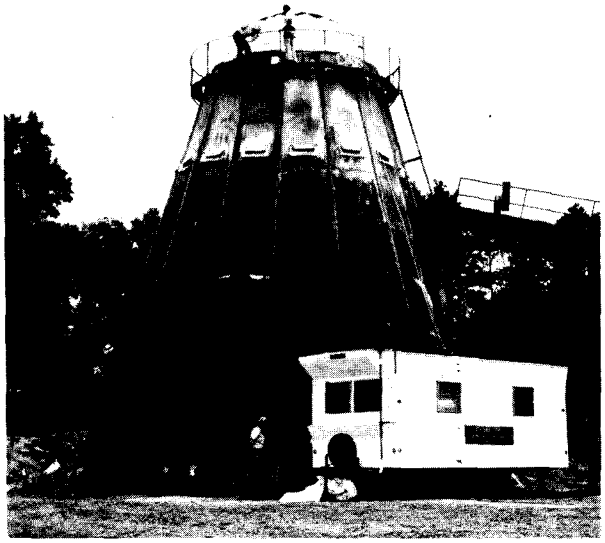

Figure 5.--A tepee burner was converted into an experimental combustion chamber. Emission monitors were installed at the tepee outlet.

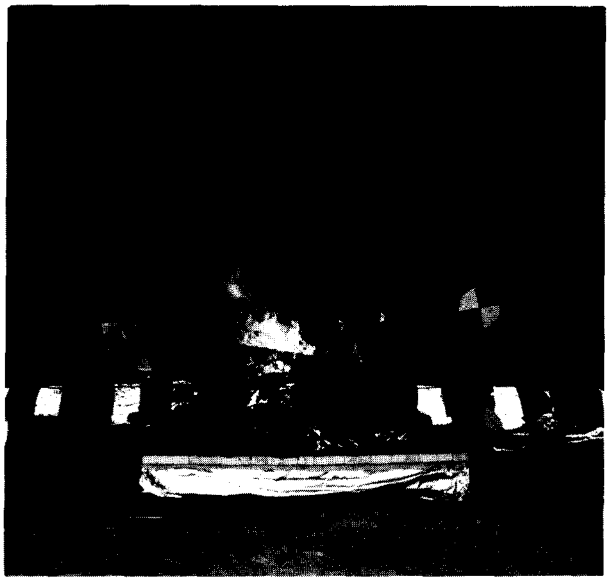

Figure 6.--A transducer-based weighing platform was used to continuously monitor combustion rate during flaming and smoldering periods.

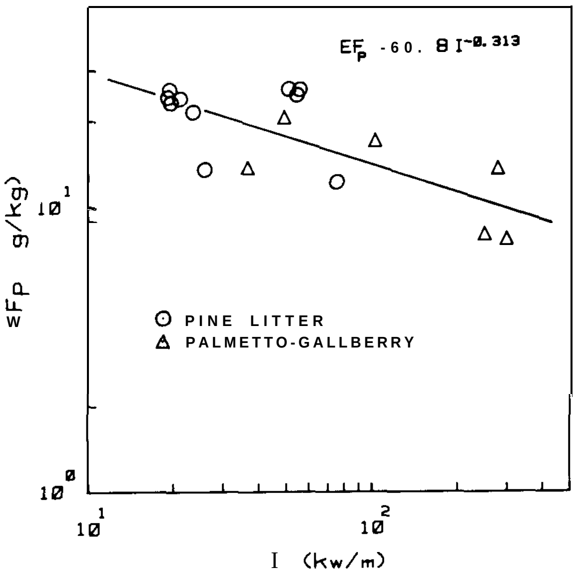

Figure 7.--Particulate matter emission factors for backfires in southern fuels as a function of Byram's fire intensity (Nelson and Ward 1980).

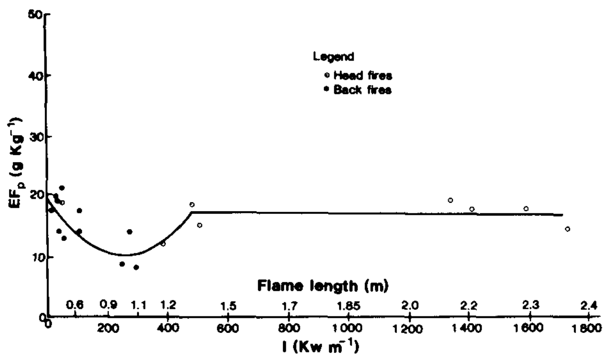

Figure 8.--Relationship between particulate matter emission factors (EF_p) and fireline intensity (I) for the palmetto-gallberry fuel type (Ward 1983).

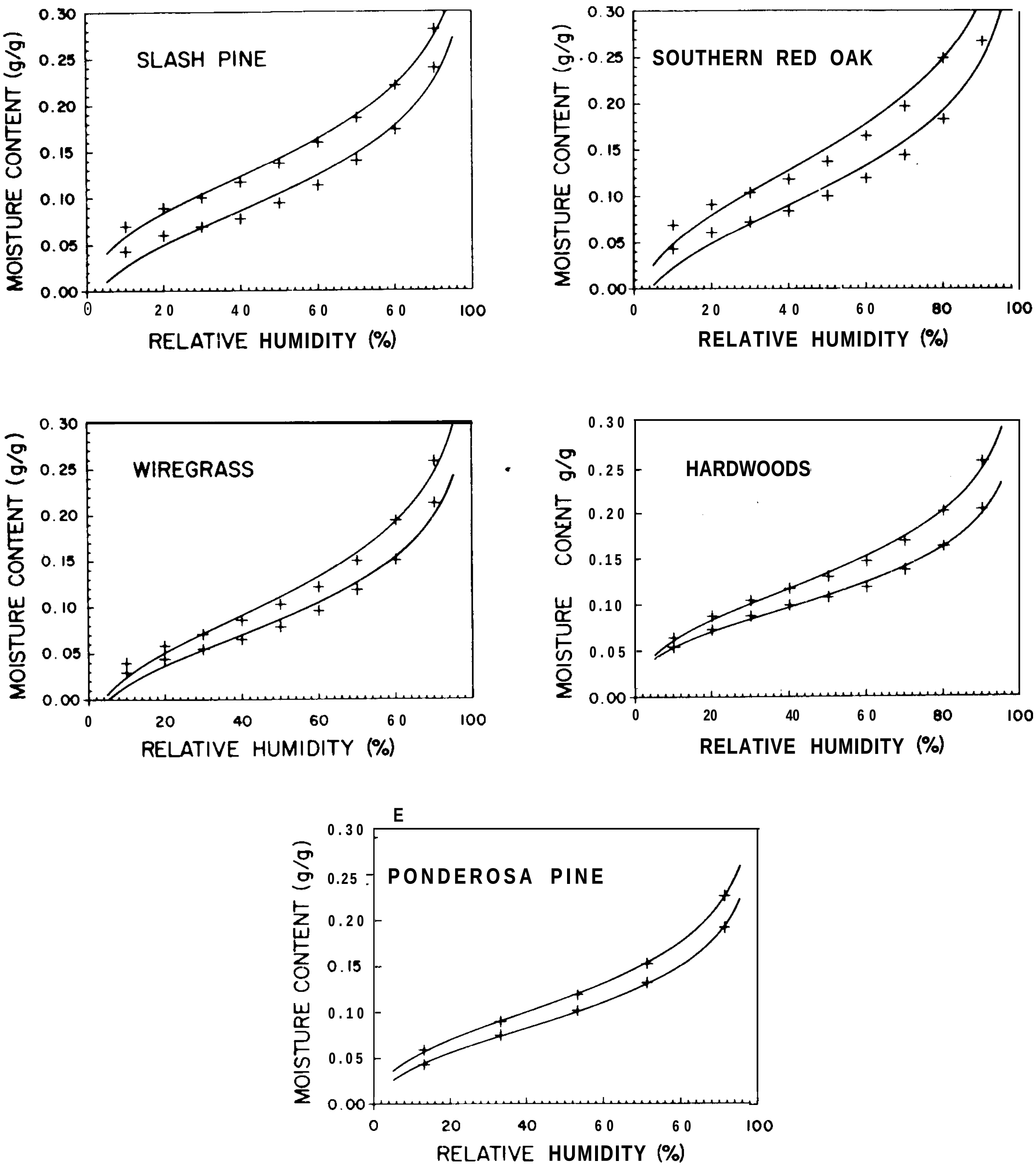

Figure 9.--Model representation of adsorption and desorption data for five forest fuels and temperatures. Upper curves are for desorption and lower curves for adsorption. The line represents model calculations; + represents experimental data (Nelson 1984).

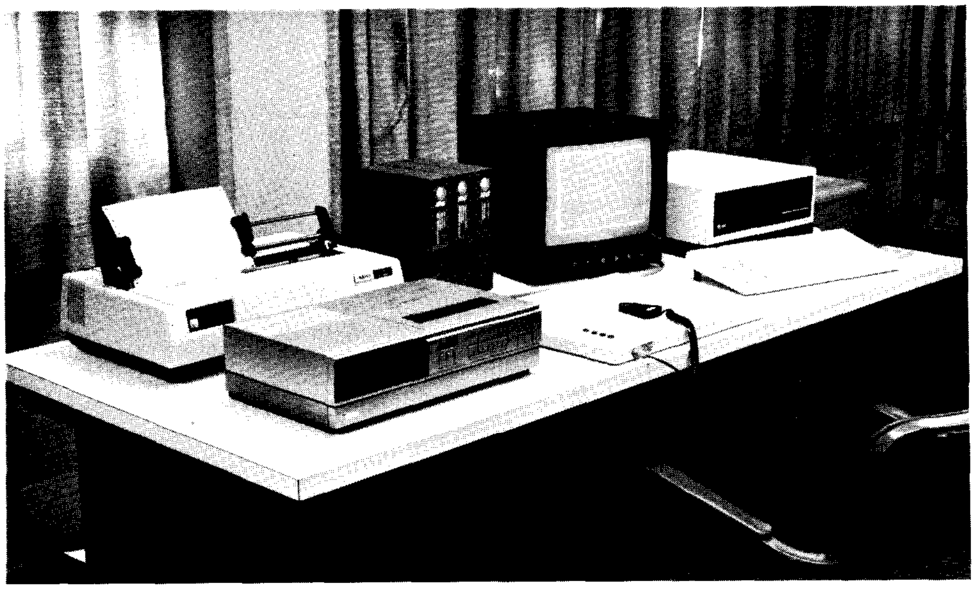

Figure 10.--A computer-based image analysis system permits rapid data reduction and analysis of fire parameters acquired by photo and video cameras.

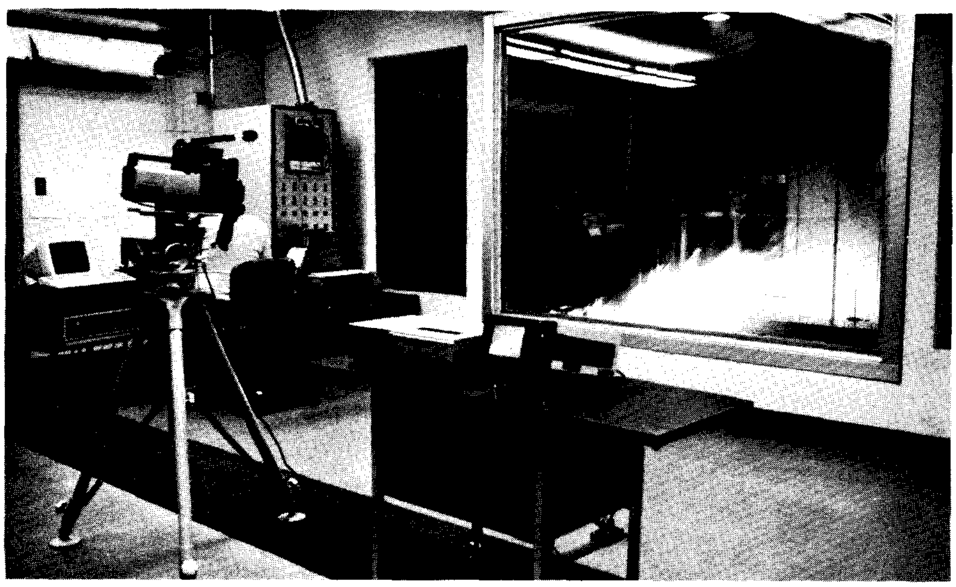

Figure 11.--Southern Forest Fire Laboratory Wind Tunnel. Small-scale fires can be burned under controlled conditions of windspeed, fuel moisture, and fuel loading.

'WEATHER AND PRESCRIBED BURNING
-WHAT'S NEW?

J. T. Paul [1]

Abstract.--Methods for transmitting weather data and uses of the data by foresters are becoming more automated. Recent work at Macon confirms the importance of atomospheric stability as a determinant of forest fire behavior. Smoke management systems currently being developed and tested, have potential future applications in maintaining highway visibility.

INTRODUCTION

Since the early 1900's when foresters first prescribed fires for southern forests, there has been little change in how they apply weather information. If it is not too wet or too dry and the wind "feels right" many foresters are accustomed to burning. Recent changes in our society and new advances in technology are bringing change to a field that has been relatively stagnant for decades. Smoke from wildfires, prescribed burning, and debris burning has been part of the South for many years and went without noteworthy public comments. The increasing concern about air quality and especially how smoke from prescribed burning may influence highway visibility has added a new dimension to the already substantial problems encountered in conducting a successful prescribed burning program.

Currently there are proposals being discussed by the administration and Congress to eliminate fire weather as a National Weather Service (NWS) program or require the service to be provided on a cost-reimbursement basis. These proposals have prompted the National Wildfire Coordinating Group to appoint a Fire Weather Team composed of meteorologists and foresters from NWS and federal and state forestry agencies to develop cost and procedural alternatives. With these alternatives a forestry agency could choose which would best meet their fire management needs if the NWS was no longer able to provide routine and special forestry forecasts.

Since the early 1930's, surface weather data have been transmitted from airport observational points across slow-speed data lines and teletype equipment (10 characters per second or less). These long-distance data lines were usually prepaid by the NWS, the Federal Aviation Agency (FAA), or the Department of Defense (DOD) into major communication hubs nationwide. A user could then tap these hubs for a monthly fee of about $50.00 and purchase of a teletype recieving unit ($1,000-$5,000). The data most useful for prescribed burning (surface observations, selected forecast data, etc.) were available on a line designated as "Service A". Data on Service A and other lines were

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transmitted in coded format. The selection and interpretation of variables of interest to prescribed burning required knowledge of international meteorological coding methods. Additionally, a meteorologist was needed to determine how these atmospheric conditions might influence burning operations.

A more recent addition to basic meteorological data service is weather facsimile. This is a nationwide network fed by an NWS computer in Washington, D. C., that provides analyzed maps and charts based on both observed and forecast weather. A user can tap the network by paying a monthly fee of about $100.00 and purchasing a weather facsimile receiver costing approximately $5000.00.

The slow speed of the data lines, the relatively high cost of paper and other items (more than $5000.00 per year at some locations), and the desirability of automating many routine processes, forced meteorologists to look at alternative methods for processing and disseminate weather data nationwide. The major consumers of weather data (NWS, FAA, DOD) developed computerized weather analysis and dissemination systems for internal use only. As these newer systems are implemented, the older teletype and facsimile networks are being phased out.

External users also needed an alternative to the older systems. The NWS responded by developing the "Family of Services," which includes medium-speed (120-480 characters per second) data lines. The "Family of Services" lines contain the data available at NWS forecast offices plus other specialized output from numerical forecast models. These lines carry all data found on the older lines, (Service A, etc.) but at a much faster rate, and cover a much larger geographic area. More data are therefore made available more quickly for analysis.

These new systems represent progress for NWS, FAA and DOD. There are potential drawbacks for a forestry agency desiring to establish a specialized forestry weather shop, however. Establishment of an in-house weather capability now requires investment in computer communication equipment, in leased land lines from their point of origin in Washington (approximately $1.50/mile/month), and in a professional meteorological staff. As an alternative if data needs are minimal, it may be cost effective to purchase selected observational and forecast data in decoded format from various commercial firms. Only low-cost terminal equipment is required for this option. Recently, there have been advertisements in meteorological journals announcing the availibility of the NWS "Family of Services" by satellite. The initial cost for a satellite dish receiver is about $2500.00 plus installation. Monthly costs depend on what data are needed and might range from $200.00 to $1000.00. The technology developed by NWS, DOD, and FAA will be of critical importance to land managers anticipating the need to develop their own weather capability. This need will be acute if NWS can no longer provide special services to foresters.

RECENT METEOROLOGICAL RESEARCH AT THE SOUTHERN FOREST FIRE LABORATORY

Atmospheric stability can accelerate or dampen the intensity of fire. A measure of stability based on observed or forecast data therefore would have obvious application in prescribed burning. A period of highly variable fire activity (May-June 1977) near the upper air station at Waycross, Georgia, was selected to screen candidate measures of atmospheric stability. The Turner Stability Class, widely used in air quality, was the best measure of atmospheric stability when related to the largest fire of the day. A larger data set (5-10 years) will be required to fully verify the relationship between Turner Stability Class and Wildfire size. This work is in progress, with estimated completion in mid-1986.

The 1978 National Fire Danger Rating System provides a method to calculate fuel moisture from a meteorological observation at an open "standard site." There are usually significant differences in meteorological observations in the open when compared to a pine stand. For example, air temperature in a pine stand is frequently higher than in the open because the wind speed inside the stand is too low to mix the air. Differences in relative humidity are at a maximum after a frontal passage when the relative humidity in the open is usually low. In a pine stand, however, relative humidity is higher, especially near the forest floor. Data from two automatic weather stations (one in the open, the second in a pine stand) about 1300 feet apart were used to estimate the magnitude of the difference in l-hour time lag fuel moisture before and after frontal passage. On the day before frontal passage, fuel moisture was 2 to 5 percent lower in the pine stand. After frontal passage and for the next 3 days, fuel moisture was 0 to 5 percent higher in the pine stand. This agrees with field reports that fire is difficult to set for 2 to 3 days after rain.

Work has been progressing on smoke management systems. A dispersion index that incorporates mixing height, transport wind speed, and Turner Stability Class has been developed and will soon be available to run on user-owned microprocessors and larger systems, or as a product in the Forestry Weather Intrepretation Systems (FWIS). The index is scaled from 0 to 100 with 0 indicating very poor dispersion and values approaching 100 indicating very strong updrafts with potential control problems. Region 6 of the Forest Service (States of Washington and Oregon) and the Georgia Forestry Commission are cooperating with the Southeastern Station in the development of a Smoke Management Screening System. The system is modular with a user front end, a "black box" computational module, and a user analysis module. The current "black box" is similiar to the Gaussian model widely used in air quality by EPA and other agencies. The system has been field tested in Washington, and comments from the field are favorable. Continuing work involves testing adaptations of other models, incorporating topography and a mountain wind model, and improving the weather data base. This work will be adapted to southern conditions and is expected to be the basis for a highway visibility model.

The Forestry Weather Intrepretation System is being fully implemented in the South and implemented for smoke management in Region 6. The Georgia Forestry Commission. is running the system on a cost-reimbursement basis on a renewable 5-year contract. By late summer of 1985 the system as run during the pilot test, plus the National Fire Danger Rating System (NFDRS), Fire Behavior,and Smoke Management, will be fully operational. Interested users should contact the Georgia Forestry Commission for access to the system. The meteorology RWU at Macon will continue to develop models for the system and consult on technical system problems.

HIGHWAY VISIBILITY - A CRITICAT, PROBLEM

Highway visibility has been a major concern expressed at this conference. The problem is especially acute in the South where low nighttime windspeeds and high relative humidity are quite common. We do not know how much smoke and a given high humidity will produce a visibility problem. In general, if the humidity is greater than about 80 percent, windspeed is less than about 5 mph, and the sky is clear or has only scattered clouds, conditions are conducive for fog formation if condensation neucleii are available. Smoke provides relatively efficient condensation neucleii since particulates are usually in the right size range and have a weak negative charge.

During light or calm winds at night, smoke tends to follow the topography to lower elevations. At most locations, this means the smoke will drain into and along a stream bed, and enter a somewhat higher relative humidity environment. Frequently, a zone of low visibility will form along streams, resulting in potentially hazardous conditions at highway bridges. Although drainage windspeeds are low (under 3 miles per hour), serious smoke hazards can occur at considerable distances from a fire, given a large enough smoke source. During a 12-hour night, a 2-1/2 mph drainage flow will carry smoke 30 miles. Most burning locations in the South are less than 30 miles from a major highway, and have at least this potential to create a safety hazard.

The solution to the visibility hazard problem, at least in part, is to first define the threshold values where humidity and smoke particles interact to produce low visibility. Second, an operational model must be developed that will integrate the humidity/smoke particle relationship with weather, topography, and fireline information into an easily used package. This is likely to be a major element of work for one or more Research Units at the Macon Fire Laboratories for the next 5 years.

WHAT DOES THE FUTURE HOLD?

There are a number of developments in progress or being discussed that will provide better weather information for forestry. In the NWS, the new generation radar, when combined with satellite information and surface observations, will provide better estimates of rainfall between reporting stations and therefore a better estimate of fuel moisture. A fire behavior model for low-intensity prescribed fires in southern forests is a likely development in the near future. This model will likely require better weather information. Larger, faster computers have the potential to provide forecasts with improved detail up to 5 days in advance and specific to the burn site.

When experienced fire weather forecasters or "old fire dogs" retire, their long experience is usually lost. Techniques now being developed at many universities under the general label of "artificial intelligence" which can capture these years of experience and make it available to the next generation of prescribed burners. Methods for receiving and using weather data are beginning to change. The Forestry Weather Interpretation System (FWIS) is an example of how technology that mixes NWS meteorological talent and monitored computerized models driven by observed and forecast weather data can be applied to forest management problems. Figure 1 is one of the products in FWIS that has been widely used for prescribed burning.

Our society is rapidly entering the "information age." It is a near certainty that forestry in general and forestry weather in particular will become more automated in the future. It is conceivable that within the next 5 to 10 years automatic weather stations, microprocessors, and satellite downlinks will be as common on the fireline as drip torches and fire rakes. Computers are unlikely to replace sound professional judgment, but they can organize and evaluate many of the complex physical/biological processes important to prescribed burning. This technology could make possible a cost-effective, comprehensive weather system for prescribed burning.
For example:

1) By maintaining a large, on-line database of weather history, a forester could enter the location and the burn weather prescription and receive the probability of occurrence of his weather prescription by hour of day and month of year.

2) If a database of stream locations, topography, roads, and bridges were available, potential highway visibility hazard areas could be identified.

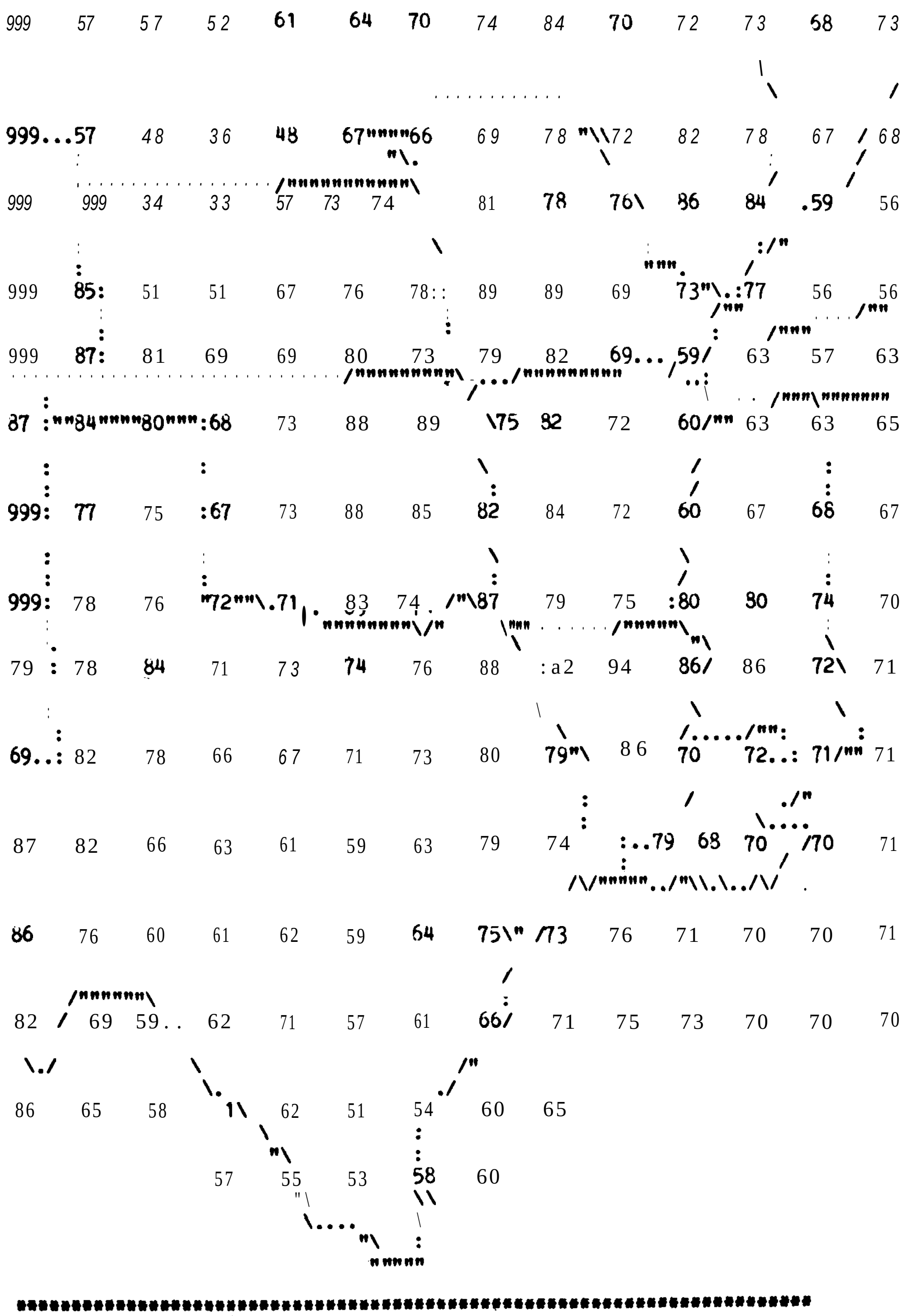
3) One may evaluate weather at a proposed burn site by using on-site weather stations that transmit observational data through a a satellite to a central location, or by using estimation procedures similar to the interpolation routine in FWIS.

4) One may provide detailed, site-specific, weather forecasts for the burn site by the hour.

5) One may equip the burn boss with a belt microprocessor with communication and voice synthesis capability. Then, using a combination of 1 through 4 above, the burner can be alerted by voice of any change in weather with an evaluation of its probable impact on the burn objective.

This may seem "Buck Rogerish" and unneeded. In the past a computerized system would have been considered at best a delightful toy, but certainly not needed to conduct a good prescribed burning program. However, our society is changing, and unless our profession makes the necessary adjustments, prescribed burning may become a historical oddity. These technological potentials will not guarantee success, but when coupled with innovative management, they provide our best chance to retain prescribed burning as a cost-effective management tool.

RELATIVE HUMIDITY MAP



Fire Research in Southern Universities

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INTRODUCTION

The first European colonists in the South had roots in cultures in which fire was an integral part of landscape management. They were met on their arrival by a culture, the Amer indian, which had reshaped the landscape over several millenia using fire (Pyne 1982). It is therefore not surprising that the southern region of the United States has led the way in the use of controlled fire in forest management and silviculture. During the past half century the consequences of wildfires and prescribed fires have been studied intensively in the South, leading to refinement of burning techniques and a greater awareness of the environmental consequences of such burning. In no other region of the world is the role of fire over the landscape so well understood. Much of what we know is a consequence of synergistic interactions between basic research carried out in universities and somewhat more application-oriented research often done jointly between universities and the research arm of the U.S.D.A. Forest Service. What follows is a report on the current status of that research and some indication of the future directions that I believe it will take.

FIRE BEHAVIOR

Studies of factors controlling ignition, fire spread, and behavior have traditionally been the province of the research arm of the Forest Service (e.g. Hough 1969 and 1973, Philpot 1970, Wendel et al. 1962). Rather elegant predictive models have been a consequence of this research (see, for example, Rothermal 1972 and Kessell 1979). Until recently, such models were viewed by basic researchers as tools to be used by fire managers to define prescriptions or predict spread of wildfires.

With the realization that on- and offsite effects of fire, as well as vegetational responses to fire, depend on fire behavior (see Christensen 1981 for review) fire spread models have become more interesting to university researchers. These models have recently been applied to studies of the distribution of savanna and forest types in the Big Thicket of east Texas. Streng and Harcombe (1982, Rice University), using Rothermal's (1972) model, showed that the successional changes in these types were largely regulated by fuel characteristics that regulate the fire cycle. Kalisz and Stone (in press, University of Florida) and Myers and Deyrup (1983) have proposed that historic and prehistoric shifts in fire behavior are responsible for the spatial patterning of sandhill and sand pine scrub communities in Florida.

Mutch (1970) proposed that features of individual plants that affect flammability (such as ether extractives, ash content, and branch demography) might have arisen through natural selection in order to increase flammability and thus guarantee a fire cycle favorable for reproduction. His argument was based on the fact that successful reproduction in many species by fire. I (Christensen 1984) have recently questioned this hypothesis and am in the midst of studies to determine to what extent properties of individual plants affect the intensity and behavior of fire in their immediate vicinity and to what extent fire behavior is a collective community property (and, therefore, not subject to natural selection in the strict sense). Our initial results (Christensen and Wilbur, in manuscript) suggest that in most shrub-dominated communities differences among individual plants contribute very little to local variations in fire behavior.

ON SITE FIRE EFFECTS

The effects of fire on the environment and vegetation are reviewed elsewhere in this volume and several recent papers (see Chandler et al. 1983, Christensen 1981 and 1984, Wright and Bailey 1982) and a considerable portion of that work has been done by university researchers. It is very difficult to generalize regarding specific effects and much remains to be done before we can accurately predict fire effects based on fire behavior.

Much of the interest in this topic has focused on mineral nutrient availability. We intuitively expect that nutrients become less available during interfire years as a greater proportion of the nutrient capital becomes sequestered as living and dead biomass. Fire causes impressively rapid mineralization of these nutrients. While research throughout the South tends to support this notion, it is clear that the magnitude of fire-caused nutrient enrichment depends on many additional factors. Nutrient increase following fire in light fuels (e.g. savannas, Christensen [1977]; pine flatwoods, McCleod and Sherrod [1984] and Richter [1980]; and Florida sandhill vegetation, Kalisz and Stone [in press]) may be modest or, in the case of nitrogen and phosphorus, nonsignificant. However, in heavy fuels, such as shrub bogs, nutrient changes may be quite dramatic (Wilbur and Christensen 1983). Studies to examine the effects of season of burning and fuel status within particular ecosystems are underway in central Florida (Archbold Station, in cooperation with the University of Florida) and on the North Carolina Coastal Plain (Duke University). Weiss (1980, University of Georgia) suggested that winter burning (the most common time for prescribed fire) might actually result in large nutrient deficits owing to leaching and an inability of winter dromant plants to take up available nutrients. However, Richter (1980) and Gilliam (1983), in a Duke University-Forest Service sponsored cooperative study, found that nutrient release and volatilization is actually greater in summer fires in flatwoods and that losses to leaching were negligible regardless of season of fire. Workman (1982) observed similar differences between summer and winter fires in turkey oak-longleaf pine stands in the sandhills of the Savanna River Plant of South Carolina.

Most inferences on nutrient availability are based on soil extraction data taken after fire. However, Schoch (1984) recently completed a study in loblolly pine plantations in the Duke Forest, Durham, NC, of the effects of prescribed fire on nitrogen mineralization and nitrification. His data, using incubation and resin bag techniques, confirm that mineralization and nitrification rates are accelerated by burning. Wilbur (1984), in a study of nitrogen and phosphorus cycling in pocosins following fire, found that fire accelerated the rates of nutrient transfer, but that the causes of this acceleration were not due to ash addition alone, but also were related to changes in postfire microclimate.

Although it is well known that microclimate and water availability are different in recently burned areas versus unburned areas (Old 1969, Peet et al. 1975), there appears to be little ongoing research in this area. Wilbur (1984) has found that soil and air temperatures just above the soil are more extreme and variable in recently burned than unburned peats and that surface horizons in burned areas tend to be much drier (owing to increased surface evaporation) and deeper horizons wetter (owing to decreased transpiration). These changes had major consequences with regard to plant survival and mineral cycling.

Several studies have dealt with the phytopathological consequences of fire, with the most celebrated case being the use of fire to control brown spot fungus (Wakeley 1970). Arvanitis and his coworkers at the University of Florida have initiated a project to evaluate injury to slash pine during prescribed burning procedures. Waldrop and Van Lear (1984, Clemson) reported on the effects of varying intensities of prescribed fire on crown scorch in loblolly pine in the South Carlina Piedmont. Their data show that survival and growth were unaffected by moderate crown scorch, however, high intensity surface fires could kill 20-30% of the co-dominant individuals. Studies of crown scorching in loblolly pine stands on the North Carolina Piedmont are presently underway at the North Carolina State University Hill Experimental Forest.

OFF-SITE FIRE EFFECTS

As Pyne (1982) pointed out, Southerners have traditionally taken for granted that fire is a natural part of the landscape. We are a bunch of "woodsburners." It was therefore something of an afront to our sensibilities when environmentalists called to our attention the effects of fire on air and water quality off-site (see McMahon 1976 and Perkins 1976). Most of these studies of smoke management and fire effects on air quality have been done by the Forest Service and the Environmental Protection Agency. I shall therefore concentrate on water quality studies, several of which have been carried out as cooperative studies between the Forest Service and Universities.

Lewis (1974) presented data indicating that nutrient losses in goundwater and stream water might be considerable as a consequence of burning in longleaf pine forests on the coarse soils of the Savanna River Plant near Aiken SC. Ken Mcleod (University of Georgia and the Savanna River Ecology Laboratory) is continuing work on this project. Coming on the heels of the Hubbard Brook study (summarized in Likens et al. 1977), ecologists were, more than ever, aware of the potential impacts of silvicultural activities off site. Several studies in western watersheds suggested that nutrient losses from burned ecosystems could significantly alter water quality down stream (see Tiedemann et al. 1978 and 1979). In 1977, a cooperative study between the Forest Service and Duke University was initiated at the Santee Experimental Forest near Charleston, SC. In this study a 160 ha watershed was managed over a 6-year period so as to simulate conventional coastal plain management practices. Prescribed fires (winter and summer) was applied to 8-10 ha (~20 a) compartments and changes in hydrologic outputs were compared to a nearby untreated watershed.

Although significant (and ephemeral) changes in soil and groundwater nutrient concentrations were noted within the burned compartments, these did not translate into significant changes in water quality (Richter et al. 1982). Douglass and Van Lear (1983) reported similar results for ephemeral streams draining two recently burned loblolly pine plantations in the South Carol ina Piedmont. In both of these studies, burned areas were separated from streams by unburned buffer zones. It might be useful to evaluate how variation in such buffer zones affects these results.

FIRE EFFECTS ON VEGETATION

There has traditional ly been considerable interest in vegetational responses to fire among university researchers. I shall summarize this work here by ecosystem.

Coastal Plain Sandhills and Sand Pine Scrub

The importance of fire in these rather xeric ecosystems was obvious to researchers 50 years ago (Harper 1914, Wells and Shunk 1931, Laessle 1958). One of the most interesting developments in the study of these ecosystems is the realization that the sand pine scrub and sandhill communities of central Florida, once thought to represent different edaphic types, form shifting mosaic determined by fire history (Kalisz and Stone, in press, Myers and Deyrup 1983). Sand pine scrub has a 20-40 year fire cycle with intense, crown-kill ing fires, whereas sandhill pine forests experience frequent (3-8 yr) low intensity surface fires. Type conversion can be brought about by a simple change in fire regime (Myers and Deyrup 1983).

Warren Abrahamson (Bucknell University) and his students have completed several studies of the vegetational patterns associated with burning in the sandy ecosystems of central Florida (see Abrahamson 1984, Abrahamson et al., in manuscript, and Givens et al. 1984). These papers have provided an understanding of fire effects over a complex vegetational mosaic. Peroni (1983) described changes in fire regimes in this region over the past 100 years.

Studies of fire effects on sandhill vegetation have been carried out by Workman (1982), in South Carolina, and May (1982), in North Carolina. Both studies emphasized the differences between summer and winter fires.

Coastal Plain Flatwoods and Savannas

There has been considerable interest in these communities, not only because of their high fire frequency and silvicultural importance, but also because they are floristically diverse and are important habitat for several rare and endangered species. Streng and Harcombe (1982) studied vegetational variations among savannas and forests of different fire histories and emphasized the two-way interaction between vegetation and fire regime. Cooperative research between the Tall Timbers Fire Ecology Station and Florida State University, supervised by William Platt has contributed significantly to our understanding of vegetatin dynamics in thes ecosystems. Davis and Platt (1984) recently reported on studies of season of burning on flowering phenology in various herb species and Evans and Platt (1984) have demonstrated the fire frequency and season of burning affect the relative success of C_3 and C_4 grasses. Harshbarger and Lewis (1976) found that 20 years of annual winter fires increased herb diversity in the flatwood pine forests of the lower coastal plain of South Carolina. Gilliam and Christensen (in manuscript), studying flatwoods in the same area, found that less frequent fires had an insignificant affect on species diversity. They also found that herb production was enhanced by winter but not by summer fires.

Savannas of the southeastern coastal plain of North Carolina have served as locations for several recent studies of fire effects on vegetation. Walker and Peet (1984, The University of North Carolina) investigated the effect of fire on herb community structure and found that variations in herb diversity were a consequence of variatins in water availability and fire frequency. Peet has a continuing research program investigating the causes of the high diversity in these ecosystems. I and my students have examined patterns of seedling establishment and production following fire in similar savannas. Successful establishment of seedlings occurs primarily in the second post-fire year when sufficient shade is available to prevent rapid drying of the soil surface. Herb production was only modestly enhanced by burning. Satterson and Vitousek (1984, The University of North Carolina) reported on root production in these savannas and Satterson is continuing work on fire effects on belowground production.

Wetlands

Fire has long been recognized as an integral part of the landscape in the Everglades complex of south Florida. Much of this research is summarized in Wade, Ewel, and Hofstetter (1980). Ronald Hofstetter (University of Miami) has an ongoing research program to integrate data on variations in fire regime over this expansive wetland with information on hydrology and microclimate in order to formulate a more realistic model of temporal and spatial distribution of plant communities. He is also interested in the effects of fire on the comparative demography and productivity of everglades gramminoids. Researchers at the University of Florida (in particular, John Ewel), as well as Dr. Hofstetter, have been interested in the role fires play in encouraging invasion of non-native species (such as Melaleuca quinquenervia) in the Everglades and how fire might be used to eliminate them.

Despite the fact that shrub-dominated wetlands (pocosins) dominate millions acres in the Southeastern Coastal Plain, little is known of fire effects in them or, for that matter, their general ecology (Richardson 1981). Interest in the peat reserves of thes ecosystems, as well as question regarding their importance to game and nongame wildlife, have stimulated considerable research in the past 5 years. I and my colleagues, with the support and cooperation of the Forest Service, have been studying vegetational responses to burning in pocosins of the Croatan National Forest. We have found that precribed fires in late winter are followed by rapid regrowth, primarily from vegetative sprouts. Production in the first two years following burning exceeds that of areas that are cleared, but not burned. After that time production is actually higher in the unburned areas. Although there is virtually no new establishment from seed fol lowing such fires, all pocosin species respond vegetatively and species diversity is largely unaffected (Christensen and Wilbur, in manuscript). More intense fires in this ecosystem (particularly in late summer) may result in considerable tree and shrub mortality, initiating a much longer term successional sequence (see Christensen et al. 1981, Christensen 1984). C. J. Richardson (Duke University) and Mark Brinson (Eastern Carolina University) have initiated research to examine the carbon budget of these bogs and plan to evaluate the role of fire in that budget.

Piedmont and Applachian Forests

Prescribed fire has only recently become a widely used management tool in these southern provinces and natural fire appears to have been limited to particular ecosystem types (Christensen 1981). Fire effects in this region have recently been reviewed by Van Lear and Johnson (1983). David Van Lear's group at Clemson has been most active in examining a wide range of fire effects in these ecosystems. Their work suggests that occasional prescribed fire in mixed pine-hardwood stands stimulates advanced reproduction in oaks only slightly (Teuke and Van Lear 1982). The effects of fire with respect to hardwood supression are quite dependent on season of burning (Van Lear and Johnson 1983).

FIRE AND WILDLIFE MANAGEMENT

There is no doubt that the first fire managers in the South, the Indian, used fire primarily to improve habitat for those game species which he depended on. Indeed, much of the pioneer research on fire in the Southeast done at the Tall Timbers Fire Ecology Station (Tallahassee, FL) was stimulated by a concern for the disappearance of the bobwhite quail. A cooperative study between the U.S. Army and North Carolina State University has recently been intitiated to determine how to integrate silivicultural fire management schemes into attempts to improve habitat for quail, deer and nongame species on the Fort Bragg Military Reservation. In the piedmont of South Carolina, David Van Lear and David Guynn of Clemson have just recently begun studies of fire effects on small mammal populations.

ECONOMICS AND PRESCRIBED BURNING OPTIONS

Much of the prescribed burning is done in the South with the intent of reducing wildfire hazard or as site preparation for silvicultural activity. However, few studies have evaluated the economic costs and benefits of such burning. Vasievich (1980, Duke University) found that economic benefits from hazard-reduction burning were dependent on the size of the burn and the years since the last fire. Research on this problem has been greatly limited by the poor quality of data (i.e., poor records on burns completed as planned and on actual losses as a consquence of burning; Vasievich, personal communication). Jon Caulfield (North Carolina State University) is in the midst of developing an economic model of wildfire risk for pine stands in southeastern North Carolina. This analysis is particularly aimed at decisions regarding postfire replanting.

PRESCRIBED FIRE AND THE MANAGEMENT OF WILDERNES

The role of wildfire in the preservation and diversity of natural ecosystems, particularly on the coastal plain, has long been recongnized (Harper 1914, Wells 1942, Garren 1943). It is equally well understood that urban and agricultural development have permanently altered fire regimes over the entire region, even in undeveloped areas (Christensen 1981). During the past decade the Nature Conservancy, in cooperation with state natural heritage programs, has acquired sever hundred thousand acres of land now set aside as wilderness. In addition, large portions of several southern National Forests have been designated as unmanaged wilderness. However, unlike the extensive wilderness in the West, We cannot depend on "let burn" policies to recreate the sort of fire regime necessary for the long term maintenance of landscape and species diversity in these areas.

I and my colleagues have recently been in the Nature Conservancy's Green Swamp Preserve (near Wilmington, NC) to develop a fire plan designed to maintain or, in some cases, increase species diversity. The emphasis in this research has been to understand the effects of variation in fire regimes in the various vegetation types in this large preserve. The details of the fire plan are as yet unclear, but the central feature will almost certainly be variation in prescription in time and space; i.e we hope to create fires that more nearly simulate the natural fire regime in this region.

FUTURE RESEARCH NEEDS AND THE ROLE OF UNIVERSITIES

Van Lear and Johnson (1983) presented an extensive list of speoific research problems related to prescribed fire. These problems range from basic ecosystem research to silvicultural research to questions related to the use of fire to manage wildlife. Considerable research is underway in the South on this entire range of problems and much of it is being done in Universities.

Following an era of research to identify the effects of fire in a general way and to broadly outline the nature of responses, we have begun to focus on the nature of variation in fire effects in order to understand more fully the consequences of varying fire regimes, both within and among different ecosystem types. The goal is the production of models that more precisely predict the full range of fire behaviors, effects, and responses. The relationship between universities and public agencies, such as the Forest Service, in this endeavor is truely synergistic. Universities can often provide facilities, manpower, and technical expertise not available otherwise in particular localities or regarding specific topics. We can also provide training in the areas of fire ecology, behavior, and management to future foresters, planners and managers. Not necessarily restrained by the necessities of a particular applied mission, university researchers are free to pursue seemingly esoteric aspects of fire ecology which may open new avenues of application that are not presently obvious. It is the communication and collaboration between university personnel and researchers in the Forest Service that will turn some of our wildest imaginings into innovative management practice.

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SESSION II

Research Recommendations

PRESENTATION OF SURVEY INFORMATION
CONFERENCE ON
PRESCRIBED FIRE AND SMOKE MANAGEMENT
IN THE SOUTH

Michael C. Long [1]

I was asked to present the results of the survey (Appendix 1) that was mailed to all pre-registered attendees of this symposium. The compilation of information reminded me of the wide variety of backgrounds of those attending, as well as the numerous objectives for the use of prescribed fire.

Seventy-three participants completed and returned the questionaire. They were categorized into groups based on experience and position; five with little or no experience, thirteen first level individuals, twenty-eight second level supervisors, and twenty-seven third level policy makers.

The indications were that problems with prescribed burning or smoke management were seldom or occasional, with no significant difference between fire or smoke as a problem. The survey sheets indicated that the second level supervisors recognized more frequent problems than the other groups.

Major reasons for prescribed burning varied. The three most commonly identified were; help prevent or make suppression of wildfire easier, benefits the managed resource, and accomplishes more than one objective at a time. Some additional objectives listed were site preparation, wildlife habitat, range improvement, hardwood control, and facilitates ability to do other tasks in the area.

Those constraints to burning listed were: not enough burning days; inadequate weather forecast to insure adherence to prescription; fear of litigation; inadequate weather forecasts for night-time and next day smoke dispersion; and not enough trained people.

In an attempt to determine some valid cost data, information was gathered on cost per acre. However, after reviewing the information received and considering the wide range provided, it is apparent that there are several methods of computation. There is great-variation on just what is included in costs per acre. I took the liberty to do little more than average the data provided. Those indicating a guess ranged from $3.20 to $5.50 per acre. The estimates ranged from $2.00 to $5.00 per acre. Those indicating actual expenses ranged from $5.12 *to* $14.65.

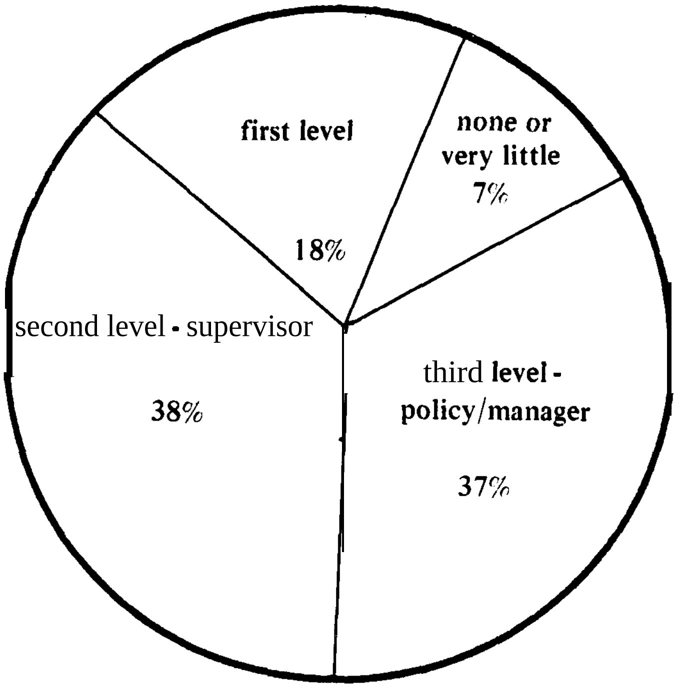
[1] Chief, Fire Control, Florida Division of Forestry

The Survey indicated the problems listed below as the most serious.

1. Public Knowledge
2. Smoke Management
3. Limited Burning Days
4. Long Term Effects on Sites
5. Government Regulations
6. Limited Information on Use of Fire in Young Stands
7. Safety Problems
8. Lack of Contractors
9. Need More Information on Fire in Hardwoods

Question 1

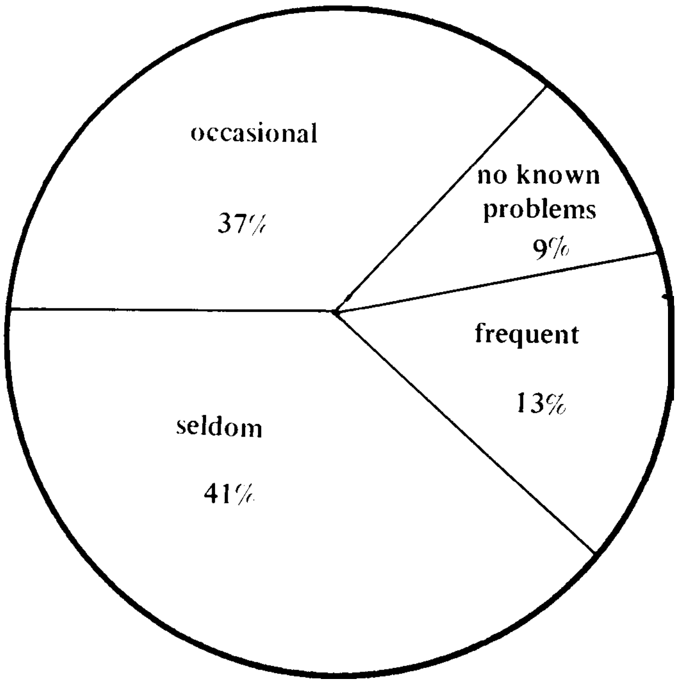
PRESCRIBED BURNING EXPERIENCE



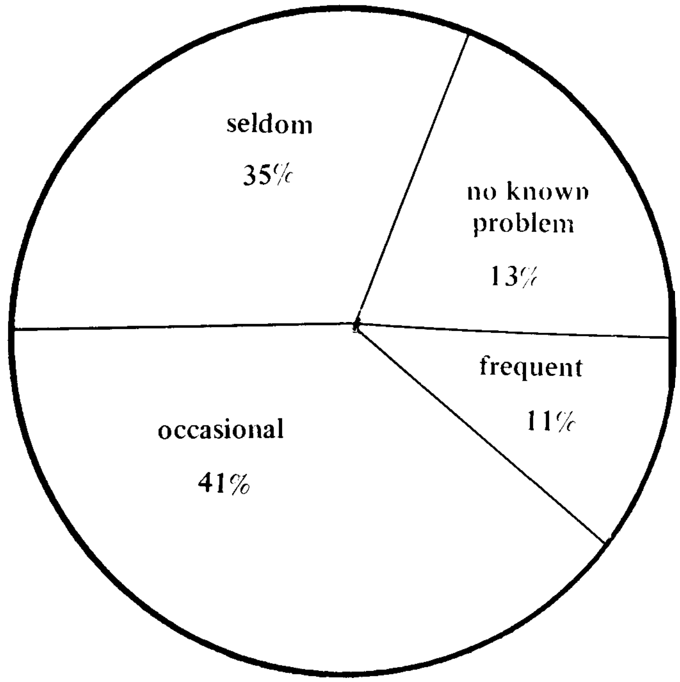
Question 2

PROBLEMS ASSOCIATED WITH:

(a) PRESCRIBED BURNING



(b) SMOKE MANAGEMENT



Question 3

REASONS FOR USING PRESCRIBED FIRE

Reason	IMPORTANCE Most	Somewhat	Least
Reduces wildfire costs	72[1] (1)[2]	13 (8)	15 (6)
Benefits the Managed Forest	59 (2)	32 (5)	9 (8)
Accomplishes more than one objective at the same time	59 (3)	29 (7)	12 (7)
Best Alternative	50 (4)	34 (4)	16 (5)
Integral part of the ecosystem	35 (5)	42 (3)	23 (3)
Inexpensive	32 (6)	47 (2)	21 (4)
Requires Little Capital Investment	27 (7)	49 (1)	24 (2)
Improves Appearance of Forest Land	05 (8)	32 (6)	63 (1)

1/ Percentage of respondents selecting this importance value.

2/ = ranking among reasons.

Question 4

PRESCRIBED BURNING CONSTRAINTS

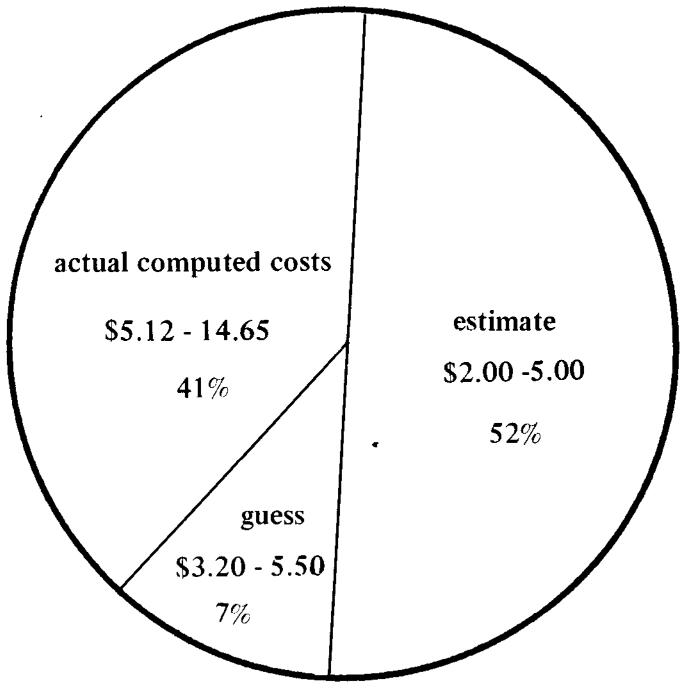
CONTRAINTS	SERIOUSNESS OF DETERRENT			
	Major	Common	Seldom	Never
Not Enough Good Burning Days	51[1/] (1)[2/]	25 (7)	11 (15)	13 (15)
Inadequate Weather Forecast to Ensure Adherence to Burn Plan	25 (2)	25 (6)	30 (8)	20 (14)
Fear Of Litigation	18 (3)	23 (8)	24 (11)	35 (6)
Inadequate Weather Forecast For Nighttime and Next Day Smoke Dispersion	16 (4)	42 (1)	12 (14)	30 (9)
Not Enough Trained People	15 (5)	40 (2)	23 (12)	22 (13)
Adverse Public Relations	14 (6)	25 (5)	34 (6)	27 (10)
Adverse Tree Growth Effects	13 (7)	11 (14)	34 (7)	42 (4)
Excessive Site Damage Potential	11 (8)	21 (10)	35 (5)	33 (8)
Inadequate Fire Effects Data For Fuel Type	11 (9)	15 (12)	36 (4)	38 (5)
Risk Of Escape To High	9 (10)	26 (3)	42 (1)	22 (12)
Inadequate Techniques For Assessing Fire Effects	9 (11)	18 (11)	39 (3)	34 (7)
General Environmental Concerns	8 (12)	26 (4)	42 (2)	24 (11)
Insufficient Expertize	8 (13)	22 (9)	28 (9)	42 (3)
Firing Techniques For Fuel Type Unknown	6 (14)	6 (15)	28 (10)	60 (2)
Inadequate Support From Management	3 (15)	13 (13)	22 (13)	62 (1)

L/Percentage of Respondents Selecting This Importance Valvue

g/Ranking Among Constraints

Questions 5 and 6

UNIT COSTS



Appendix 1

Dear Preregistrant:

Prior to attending the "Conference on Prescribed Fire and Smoke Management in the South" would you take a few minutes to answer some questions about prescribed burning? Your answers will be summarized, along with responses from other attendee's by Mike Long, Florida Division of Forestry. Your response should be sent to Mike by August 31, 1984. A pre-addressed envelope is enclosed for your convenience.

1. My experience in prescribed burning is (check most appropriate):

   First level

   Second level - Supervisor

   Third level - Policy/Manager

   None or very little

2. Problems associated with (a) prescribed burning/(b) smoke management conducted within my area of responsibility are (check most appropriate):

a	b		a	b	
_	_	Frequent	_	_	Seldom
_	_	Occasional	_	_	No known problems

3. My reasons for prescribed burning are ranked in order of equal importance (l-3). Items marked with a "1" are most important.

   Inexpensive

   Benefits the managed resources

   Requires little capital investment

   Integral part of the ecosystem

   Helps prevent or makes the suppression of wildfires easier

   Improves appearance of forest land

   Accomplishes more than one objective at the same time

   Best alternative

   Other(explain) ____

   ____

4. Rank in order of equal importance (l-4) the following prescribed burning constraints. Items marked with a "1" are, in my judgement, the most serious deterrents; a "4" indicates the item is not a deterrent.

   Risk of escape too high

Adverse public reaction

General environmental concerns

Insufficient experience

Inadequate weather forecasts for night time and next day smoke dispersion

Inadequate weather forecasts to ensure adherence to prescription

Inadequate techniques for assessing fire effects

High potential for excessive damage to site

Adverse effects on tree growth

Firing technique for fuel type unknown

Not enough good burning days

Inadequate fire effects data for fuel type

Not enough trained people

Inadequate support from management

Fear of litigation

Other (explain) ____________________

____

5. What is your cost to prescribe burn? $_ to $ _per acre.

6. Are the unit costs shown in question number 5 a:

Guess? Estimate? Actual computed costs?

7. What do you consider the most serious problems, unknowns or ambiguities regarding fire use/control in the South? (Explain) ____________________

____

DALE D. WADE
Planning Committee

WORKING GROUP REPORTS

At this point in the conference the attendees were charged with collectively developing a list of the five most important unresolved problems facing prescribed burners in the South and were assigned to one of three discussion groups. Each group was also asked to identify the major stumbling blocks to the technology transfer and implementation process. A predesignated leader guided the discussion in each group and prepared a summary of their deliberations. Group leaders and members of the planning committee then met and merged the individual group reports into a tentative combined report. The conferees were reconvened in general assembly and the individual group summaries read and approved. Finally the overall consensus report was presented, modified in open session, and officially adopted by the assembly.

The three individual group reports and the conference consensus report follows.

GROUP 1

WALTER HOUGH - CHAIRPERSON
ASSISTANT DIRECTOR, SOUTHERN FOREST EXPERIMENT STATION
NEW ORLEANS, LOUISIANA

RESEARCH NEEDS

1. Economics of prescribed burning

    a. Cost savings (potential) of future site prep due to prescribed burning,

2. Expand acreage treated with prescribed fire especially in young pine stands.

3. a. Ignition techniques to widen the burning window.

    b. Better fire behavior/effects predictors.

    c. Improved smoke management.

4. Better fire effects predictors

    a. Relate growth loss to fire intensity, especially in young pine stands.

    b. Effects of early burning on bole quality and branch characteristics.

5. Smoke management of residual or smoldering combustion products

    a. Mop-up techniques to reduce smoke (e.g. retardant for stumps and snags).

    b. Prediction of smoldering capability using preignition conditions such as fuels and moisture content.

NON-RANKED MINOR ISSUES

Public attitudes

Herbicide - prescribed burning interactions

Thinning with prescribed fire

Prescribed Fire effects on hardwoods by species

Live fuel moisture effects on fire behavior

Line production rates in fire control

GROUP 1

TECHNOLOGY TRANSFER NEEDS

1. Professional and technical education and training

   a. Information sources made available to all

   b. Simplify research publications such as NFDRS

   c. Develop more prescribed burning training courses

2. Public Education

   a. Inform public about benefits from prescribed burning practices

   b. Reach target groups such as environmentalists, legislative bodies, etc.

   c. Use more public relations, news releases, "canned" programs and popular articles in widely read magazines.

3. Identify technology transfer responsibilities.

IMPLEMENTATION NEEDS

1. Lack of qualified people and equipment to do total job

2. Lack of timely and accurate weather forecasts

3. Lack full commitment of management during periods of good burning weather.

4. Lack of adequate planning and evaluation

5. Too many laws and regulations

NON-RANKED MINOR ISSUES

Lack of incentives for non-industrial, private landowners

Lack of incentives for consultants

Absentee land ownership

Lack of legal knowledge and assistance

GROUP 2

LEONARD A. KILIAN, JR. - CHAIRPERSON
STATE FORESTER, SOUTH CAROLINA STATE COMMISSION OF FORESTRY
COLUMBIA, SOUTH CAROLINA

RESEARCH NEEDS

1. Guides to Estimate - Growth Loss, SBP Sites, Age Stress due to fire resulting in insect and pathogens as a result of pine scorch.

2. Better weather forecasts that are site specific.

3. Oak regeneration - prescribed fire effects.

4. Methodology improvement

   a. Practical method of determining tons/acre fine fuel

   b. Smoke density gauge - on highways during burns

   c. Better emission factor guide or estimate for fuel types and amounts.

   d. Useable field measurement techniques for flame lengths, rate of spread, etc.

5. Methods and Techniques in use of aerial ignition in wildfire control.

TECHNOLOGY TRANSFER NEEDS

1. What and where training is available in Principles of Fire Behavior. Request training film or video in fire safety, fire line construction using current and new practices. Also demonstration of aerial ignition.

2. Workshops in prescribed burning in more than one age class and more than one fuel type.

3. Weather forecast that are site specific.

4. Liability checklist and checklist or guidelines on what to look for in insurance coverage.

5. Develop system of dissemination of what information is available.

GROUP 2

IMPLEMENTATION NEEDS

1. Public endorsement of prescribed burning by T.V., other media and lobby legislatures for endorsement.

2. Implement scheduling of emissions (Smoke Management Plan) within airsheds independent of user.

3. Weather forecast site specific.

4. Get Turner Stability Index to user in field in useable, predictable manner. (Other stability guides?)

5. Get wetting agent info to field user.

GROUP 3

BARRY F. MALAC, CHAIRPERSON
TECHNICAL DIRECTOR, WOODLANDS DIVISION, UNION-CAMP CORPORATION
SAVANNAH, GEORGIA

RESEARCH NEEDS

1. A coordinating council should be formed between researchers, extension specialists and users to keep fire research from being fragmented and to provide a forum for frequent interaction between researchers, users, local groups and regional/national programs. The council could be under the auspices of the Prescribed Fire Working Group of the National Wildfire Coordinating Group or it could be patterned after the South Florida Interagency Wildland Fire Council. Its objectives would include:

   a. Identification of more narrowly focused research tied to specific forest types, geographic units, etc.

   b. Better documentation and evaluation of prescribed fires (acres burned, conditions, techniques, success or failure, problems, etc.).

   c. Explore alternative sources of funding research.

   d. Determine feasibility of establishing a university/Forest Service/industry prescribed fire cooperative.

2. Improved prescribed burning techniques.

   a. Relative effectiveness of spot vs. line firing techniques.

   b. Scaled down equipment and techniques for small privately owned timber tracts.

   c. Critical cost/benefit analyses using total costs (e.g. equipment, materials, overhead, risk, priorities, etc.).

3. Develop prescriptions and techniques for burning young pine stands - both planted and natural.

4. Fire damage predictions.

   a. Test efficacy of existing crown scorch predictors.

   b. Quantify relationship between various levels of crown scorch and resultant tree growth, especially in young pine stands.

GROUP 3

NON-RANKED MINOR ISSUES

Educate public regarding benefits of prescribed fire.

a. Base on fact fire has historically been an integral part of southern ecosystems.

b. Identify obstacles to effective communication.

Identify smoke related health hazards to fire crews.

Develop prescription fire guides for managing hardwood stands.

TECHNOLOGY TRANSFER NEEDS

1. Education and Training (State-of-the-art reports in non-technical manuals, demonstrations, show-and-tell, workshops (live or video taped)).

   a. Public at large on the national, regional and local level (teacher conservation workshops, 4-H Clubs, Future Farmers, etc.).

   b. Employers (forest managers) - opportunities, liabilities, cost/benefit.

   c. Employees (the "burners") - techniques, hazards, responsibilities.

2. Summaries of state laws and regulations (in plain English).

   a. Court cases and their desposition.

IMPLEMENTATION NEEDS

Included in Technology Transfer

JOHN M. BETHEA - CHAIRPERSON
DIRECTOR, FLORIDA DIVISION OF FORESTRY
TALLAHASSEE, FLORIDA

RESEARCH CONSENSUS

1. Economics of prescribed burning
2. Residual smoke and dispersion problems
3. Better fire behavior data to expand the prescribed burning window- especially in young stands
4. Estimating direct and indirect growth loss associated with various scorch levels
5. Better site specific weather forecasts for prescribed burning
6. Prescribed fire management guidelines for hardwood management
7. Aerial ignition as a technique for prescribed - and wild-fire control
8. Development of methodology and equipment for the non-industrial private forest landowner
9. Prescribed fire coordinating council
10. Better method to estimate available fuel in the field
11. Methods to reduce emissions for various fuel types and firing techniques
12. Identify health hazards for fire crews from smoke
13. Monitor and cultivate public attitudes

TECHNOLOGY TRANSFER CONSENSUS

1. Professional and technical education and training
2. Public education and training
3. Identify technology transfer responsibilities
4. Checklist for what to look for in insurance coverage and liability
5. Summarize state laws and regulations

IMPLEMENTATION CONSENSUS

1. Better equipment and more qualified people
2. Need commitment of management
3. Better planning, evaluation and feedback
4. Realistic laws and regulations needed
5. More timely and accurate site specific weather forecasts
6. Development of procedures for evaluating and coordinating atmospheric smoke loading

CONFERENCE ON PRESCRIBED FIRE AND SMOKE MANAGEMENT IN THE SOUTH

Ramada Inn Central, Atlanta, Georgia, September 12-14, 1984

Wrap-Up Remarks by Jerry A. Sesco, Assistant Director
Southeastern Forest Experiment Station

Let me say again that we are delighted so many of you--the key forest managers and leaders in prescribed fire and smoke management in the South--attended this workshop and symposium. Attendance and participation far exceeded our expectations. There was also a good balance of representation among participants from industry, federal and state agencies, and universities. I believe the excellent attendance and active participation, especially during the discussion sessions, indicated a strong interest in, and concern for, the subject of this workshop.

The objectives of this symposium were to "review current prescribed fire and smoke management practices in the South, present research developments, identify key problems, and develop recommendations for industry, state and federal programs." As I reflect back over the past 2½ days, I believe the symposium met this objective.

On the first day, we were brought up to date on the prescribed fire and smoke management programs and problems of the southern forestry community. We had speakers representing the federal, state, industry, consultant, and legal perspectives.

On the second morning, we were apprised of new developments and research progress.. Yesterday afternoon and this morning, we began charting future direction in research, technology transfer, and implementation.

As Dr. Ross indicated in his opening remarks, the Southeastern Station has some major decisions to make about our prescribed burning and smoke management research. During the next year, we will be determining research directions for the next 5 years and we need your help and guidance. I assure you that the information developed here represents major input into our new program. As we draft charters for the new program, we will be seeking additional input and review from you.

Let me add a few words of restraint, however. We in research, like you, are constrained by budgets and personnel ceilings. Obviously, we will not be able to do all the research you have recommended. It is possible the project that you as an individual feel strongly about may not be in our new charter. As one speaker pointed out yesterday, there is a cost attached to priority. Research is expensive; fire research is very expensive; and there are limited dollars. Also, some of the research you have suggested may be done at other federal fire research facilities and at universities around the country rather than at the Macon Fire Lab. Other research may not be possible without your cooperation and assistance.

Throughout this symposium, speakers pointed out time and time again that although prescribed fire is useful, societal attitudes are changing and restrictions on its use may increase. As the rural/urban interface expands, we will face more and more questions about the pollution and nuisance aspects of prescribed fire. I believe your concerns about this problem were evident in the discussions about the need for public education on prescribed fire.

I contend we can counter the attacks on our technology more confidently if we have solid scientific data to back up our actions. We will continue to provide the needed scientific information.

In summary, I believe this symposium has been an effective forum for the statement of your ideas and priorities. Again, we thank all of you for attending.

Special recognition must be given to the session moderators for the outstanding job they did in organizing and directing their sessions. We would also like to gratefully acknowledge the work of the following people who served on the planning committee *for this syposium: Thomas H. Ellis, Gordon D. Lewis, James D. Lunsford, Hugh E. Mobley, J. Hugh Ryan, Dale D. Wade, and Deborah K. Offutt.

Finally, I extend to you an invitation to visit the Macon Fire Laboratory and see firsthand some of the research we are doing.

APPENDIXES

APPENDIX I

Agenda

CONFERENCE ON PRESCRIBED FIRE AND SMOKE MANAGEMENT IN THE SOUTH

Tuesday Night, 9/11/84

7:00 - 9:00 Registration - Ramada Inn Central

Wednesday, 9/12/84

Day 1, Session I

Overviews of Prescribed Fire and Smoke Management Programs & Problems

Day 1 Morning Moderator - John W. Mixon; Director, Georgia Forestry Commission; Macon, GA

8:00	Registration
9:50	Call to Order - John W. Mixon
9:55	Welcome - Eldon W. Ross; USDA FS, Director, Southeastern Forest Experiment Station, Asheville, NC - Michael P. Mety; Chairman, Southern State Foresters Association and State Forester, Louisiana
10:10	Keynote Speaker - Benton H. Box; Dean, College of Forest and Recreation Resources, Clemson University; Clemson, SC
10:35-12:30	States
10:35-	TX, LA, MS - Bruce R. Miles - State Forester, Texas
11:00-	AL, FL, GA - C. W. "Bill" Moody - State Forester, Alabama
11:25-	VA, NC, SC - H. J. "Boe" Green - State Forester, North Carolina
11:50-	AR, KY, OK, TN- Roy C. Ashley - State Forester, Tennessee
12:15-	Discussion of State overviews
12:30-1:30	Lunch (on your own)

Day 1 Afternoon Moderator - W. Howard Hanna; Manager, Timber Research & Development, Container Corp. of America; Fernandina Beach, FL

1:30-2:30 Industry

1:30- W. D. Baughman; Southern Woodlands Manager, Westvāco Corp.; Summerville, SC
1:55- R. A. "Dick" Williams; Management Forester, Georgia-Pacific Corp.; Crossett, AR
2:20- Discussion of Industry overviews

2:30-3:05 Consultant

2:30- L. Keville Larson; Larson & McGowan Inc.; Chairman, National Association of Consulting Foresters; Mobile, AL
2:55- Discussion of Consultant overview
3:05-3:20 Coffee Break

3:20-3:55 Federal

Dick A. Cox; USDA FS, Director, Aviation & Fire Management; R-8; Atlanta, GA
3:45- Discussion of Federal overview

3:55-4:30 Legal Aspects

William C. Siegel; USDA FS, Project Leader, Southern Forest Experiment Station; New Orleans, LA
4:20-4:30 Discussion of Legal Aspects
7:00- Banquet - Emcee - James Turner, Georgia Forestry Commission, Fire Chief - Retired
Speaker - Fred W. Haeussler; Vice President, Society of American Foresters and Land Manager, Union-Camp Corp.; Savannah, GA

Thursday 9/13/84

Day 2, Session I cont'd

Day 2, Session I Moderator - Charles W. Philpot; USDA FS, Director, Forest Fire & Atmospheric Science Research; Washington, DC

8:00-10:40 State-of-the-Art Presentations

8:00 Smoke Management (including regulations)
- Hugh E. Mobley; Alabama Forestry Commission; Montgomery, AL
8:25- Weather and Fire Danger Rating
- John G. Shepherd; North Carolina Department of Natural Resources and Community Development; Raleigh, NC

8:50- Prescribed Fire and Fire Effects
- David H. Van Lear; Professor, College of Forest and Recreation Resources, Clemson University; Clemson, SC

9:15- Discussion

9:25-9:40 Coffee Break

9:40- Aerial Ignition--Ping-Pong Balls
- John W. Gnann; Manager, Forest Development, Woodlands Division, Union-Camp Corp.; Savannah, GA

10:05- Aerial Ignition--Flying Drip Torch
- Grady E. Stevens; Chief, Helicopter Division; International Paper Co.; Natchitoches, LA

10:30- Discussion

10:40-1:35 <u>Research Update</u>

USDA, Forest Service, Southeastern Forest Experiment Station, Southern Forest Fire Laboratory; Macon, GA

10:40- Fire Science Adaptations for Southeastern U.S.
- Dale D. Wade, Acting Project Leader

11:05- Combustion Processes in Wildland Fuels
- Charles K. McMahon, Project Leader

11:30- Forestry Weather Data Systems
- James T. Paul, Project Leader

11:55-1:00 Lunch (on your own)

1:00- Universities (Research) - Norman Christensen; Department of Botany, Duke University; Durham, NC

1:25-1:35 Discussion

Day 2, Session II

Future Direction

Day 2, Session II Moderator - Michael C. Long; Florida Division of Forestry; Tallahassee, FL

1:35- Introduction & Charge to Discussion Groups - Michael Long

1:50- Results of Questionnaire - Michael Long

2:05- Discussion & break into predesignated Groups to develop fire-related prioritized list of not more than 10 general needs each with not more than 3 specific component questions

3:15-3:30 Coffee Break

3:30- Discussion Groups continue

Group Leaders

1 - Walter A. Hough; USDA FS, Assistant Director, Southern Forest Experiment Station, New Orleans, LA

2 - Leonard A. Kilian, Jr.; State Forester, South Carolina State Commission of Forestry; Columbia, SC

3 - Barry F. Malac; Technical Director, Woodlands Division, Union-Camp Corp.; Savannah, GA

Friday, 9/14/84

Day 3, Session II cont'd

Day 3, Session II Moderator - John M. Bethea; Director, Florida Division of Forestry; Tallahassee, FL

8:00-8:30	National Smoke Management Course Update - J. Hugh Ryan - South Carolina Forestry Commission; Columbia, SC
8:30-9:30	Group Reports & Discussion
8:30-	Group 1 - Walter A. Hough
8:45-	Group 2 - Leonard A. Kilian
9:00-	Group 3 - Barry F. Malac
9:15-	Consensus Report - John M. Bethea
9:30-9:45	Coffee Break
9:45-11:30	Discussion and Final Report
11:30-	Fire Research in the South - Washington Office Perspective - Charles W. Philpot; USDA FS, Director, Forest Fire & Atmospheric Science Research; Washington, DC
	Wrap-Up - R. Sid Moss, State Forester, Mississippi Forestry Commission, Jackson, MS - Jerry A. Sesco; USDA FS, Assistant Director, Southeastern Forest Experiment Station, Asheville, NC

Appendix II

LIST OF ATTENDEES

Adkins, C. Wayne - USDA Forest Service, Southern Forest Fire Laboratory, Rt. 1, Box 182A, Dry Branch, GA 31020

Anderson, Earl B. - USDA Forest Service, Riverside Fire Laboratory, 4955 Canyon Crest Drive, Riverside, CA 92507

Andrews, Alan - Georgia-Pacific Corp., P. 0. Box 158, East Palatka, FL 32031

Ashley, Roy - Tennessee Division of Forestry, 701 Broadway, Nashville, TN 37167

Ashworth, Scott T. - Union-Camp Corp. Altamaha Forest, P. 0. Box 87, Baxley, GA 31513

Barb, J. L. - Union-Camp Corp., Woodlands Division, Franklin, VA 23851

Barnett, Mark D. - Hammermill Paper Co., 805 Overhill Court, N.W., Atlanta, GA 30328

Bartle, W. E. - Catawba Timber Co., 917 Sherwood Circle, Lancaster, SC 29720

Baughman, W. D. - Westvaco Corp., P. 0. Box 1950, Summerville, SC 39484

Bennett, Joseph W. - Daniel Boone National Forest, 100 Vaught Rd., Winchester, KY 40391

Bethea, John M. - Florida Division of Forestry, 3125 Conner Blvd., Tallahassee, FL 32301

Birch, John E. - USDI Bureau of Land Management, Interior Building, Washington, DC 20240

Bowling, Doug - International Paper Co., Southlands Experiment Forest, Rainbridge, GA 31717

Box, Benton H. - College of Forest & Recreation Resources, Clemson University, Clemson, SC 29631

Boyer, William D. - USDA Forest Service, C. W. Andrews Forestry Sciences Lab., DeVall St., Auburn University, AL 36849

Braford, William L. - Virginia Division of Forestry, P. 0. Box 386, Farmville, VA 23901

Brown, Johnny - Gilman Paper Co., P. 0. Drawer 878, St. Marys, GA 31558

Bryant, Jerry - Weyerhaeuser Co., P. 0. Box 7, Mountain Pine, AR 71956

Burnett, James - U.S. Fish & Wildlife Service, P. 0. Box 699, Gautier, MS 39553

Butts, David - USDI National Park Service, 3905 Vista Ave., Boise, ID 83705

Carroll, John - Virginia Division of Forestry, P. 0. Box 100, Salem, VA 24153

Cnambers, John W. - Assistant Director, Aviation & Fire Management, USDA Forest Service, P. 0. Box 2417, Washington, DC 20013

Christensen, Norman - Department of Botany, Duke University, Durham, NC 27706

Cl eaves, David A. - USDA Forest Service, Riverside Fire Laboratory, 4955 Canyon Crest Drive, Riverside, CA 92507

Clonts, Thomas M. - Stone Container-Forest Products Division, P. 0. Box 21607, Columbia, SC 29221

Cochran, Gary - Union-Camp Corp., P. 0. Box 1726, Montgomery, AL 36102

Cohen, Jack - USDA Forest Service, Riverside Fire Laboratory, 4955 Canyon Crest Drive, Riverside, CA 92507

Cole, Frank T. - U.S. Fish & Wildlife Service, Merritt Island Refuge, P. 0. Box 6504, Titusville, FL 32780

Coloff, Stan - Air Resource Program Manager, USDI Bureau of Land Management, 18th & C St., N.W., Washington, DC 20240

Cox, Dick A. - R-8 Aviation & Fire Management, USDA Forest Service, 1720 Peachtree Rd., N.W., Atlanta, GA 30367

Dahlem, Michael J. - Weyerhaeuser Co., Star Route, Box 100, Wright City, OK 74766

Dale, Donald - Weyerhaeuser Co., P. 0. Box 388, DeQueen, AR 71832

DeBrunner, L. Earl - Department of Forestry, Auburn University, Auburn, AL 36849-4201

Dressel, Armin T. - International Paper Co., Rt. 3, Box 690, Camden, AR 71701

Emerson, Steve - Weyerhaeuser Co., Star Route, Box 100, Wright City, OK 74766

Fene, Kim M. - USDI National Park Service, 75 Spring St., S.W., Atlanta, GA 30303

Fields, R. G. - Union-Camp Corp., Woodlands Division, Franklin, VA 23851

Fischer, R. J. - Weyerhaeuser Co., Star Route, Box 100, Wright City, OK 74766

Foster, R. Fred - USDA Forest Service, 8 Turnberry Place, Arden, NC 28704

Freeman, Duane R. - Mark Twain National Forest, 401 Fairgrounds Rd., Rolla, MO 65401

Frisch, Jim - Crown Zellerbach Co., P. 0. Box 400, Bogalusa, LA 70427

Gayle, James A. - Mid-South Region, Lands & Timber, International Paper Co., 300 Knight Office Place, Suite 100, Shreveport, LA 71105

Gnann, J. W. - Union-Camp Corp., P. 0. Box 1391, Savannah, GA 31402

Goff, Michael - Weyerhaeuser Co., P. 0. Box 26, Kosciusko, MS 39090

Goodowns, Charles - Gilman Paper Co., P. 0. Drawer 878, St. Marys, GA 3155%

Gore, Ray - Gilman Paper Co., P. 0. Drawer 878, St. Marys, GA 31558

Greene, Thomas - Rt. 4, Box 675, Denham Springs, LA 70726

Haeussler, Fred W. - Union-Camp Corp., P. 0. Box 1391, Savannah, GA 31402

Hanna, Howard - Container Corp. of America, P. 0. Box T, Fernandina Beach, FL 32034

Hardage, Tom - Mississippi Forestry Commission, 908 Robert E. Lee Building, Jackson, MS 39201

Hargrove, William C. - Georgia Forestry Commission, Rt. 6, Box 169, Waycross, GA 31501

Harper, Mike - Union-Camp Corp., P. 0. Box 1726, Montgomery, AL 36102

Haywood, Dave - USDA Forest Service, Southern Forest Experiment Station, 2500 Shreveport Highway, Pineville, LA 71360

Holley, Lester - Department of Forestry, Box 8002, NC State University, Raleigh, NC 27695-8002

Hooven, Lynn - Georgia Forestry Commission, P. 0. Box 819, Macon, GA 31298-4599

Hough, Walter A. - USDA Forest Service, Southern Forest Experiment Station, T-10210 PSB, 701 Loyola Ave., New Orleans, LA 70113

Hulick, Kenneth H. - USDI National Park Service, Chattahoochee River NRA, 1900 Northridge Rd., Dunwoody, GA 30338

Husari, Susan - Everglades National Park-Resource Management, P. 0. Box 279, Homestead, FL 33030

Hutchinson, Duncan A. - USDI National Park Service, Congaree Swamp NMP, Suite 607, 1835 Assembly St., Columbia, SC 29201

Jeffrey, Bobby G. - International Paper Co., P. 0. Box 278, Sheridan, AR 72150

Johansen, Ragnar W. - USDA Forest Service, Southern Forest Fire Laboratory, Rt. 1, Box 182A, Dry Branch, GA 31020

Johnson, Lionel R. - 1531 Eldonlas Court, Stone Mountain, GA 30087

Johnson, Randall - Georgia-Pacific Corp., P. O. Box 1095, Walterboro, SC 29488

Johnson, Raymond - ITT-Rayonier, P.O. Box 393, Waycross, GA 31501

Jordan, Freddie - Mississippi Forestry Commission, 908 Robert E. Lee Building, Jackson, MS 39201

Kacer, Kevin G. - Cumberland Island National Seashore, P.O. Box 806, St. Marys, GA 31558

Kast, Kevin - Crown Zellerbach Co., P. O. Box 400, Bogalusa, LA 70427

Kautz, Edward W. - USDA Forest Service, 310 W. Wisconsin Ave., Milwaukee, WI 53203

Kennedy, Edd III - MacMillan Bloedel Inc., 808 Walnut St., Monroeville, AL 36460

Kilian, Leonard - South Carolina Forestry Commission, P. O. Box 21707, Columbia, SC 29221

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