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Fire Management Notes

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Contents

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Send suggestions and articles to Chief, Forest Service (Attn: Fire Management Notes), P.O. Box 2417, U.S. Department of Agriculture, Washington, DC 20013.

Cover: The Butte Fire on the afternoon of August 29, 1985, 30 minutes before 73 persons were forced to deploy fire shelters. A forthcoming issue will contain detailed information on this incident, including meterology, fire behavior, and shelter deployment.

DESCON: A Proven Method of Reducing Wildfire Suppression Costs

Douglas J. Riley

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Most, if not all, wildfire management agencies are currently facing the prospect of reduced budgets, and are looking for ways to reduce wildfire management costs without adversely affecting either the safety of fire management personnel or environmental quality. One proven method of reducing wildfire management costs that has been successfully utilized by a number of agencies is DESCON (Designated Controlled Burn).

DESCON refers to the process of controlling a wildfire through the use of existing barriers, (either constructed roads, firebreaks, stone fencerows) or natural (streams, lakes, rock outcroppings). These barriers can be used as they are, or they can become places from which to counterfire. The utilization of constructed or natural barriers has several benefits:

1. Because the need to utilize heavy equipment (such as dozers, tractors, or engines) in rugged terrain is reduced, repair costs are less, as are the costs of equipment upkeep or rental.
2. Use of existing barriers greatly reduces the need for hand-constructed firelines, thereby resulting in reduced personnel costs.
3. Taking advantage of existing barriers increases personnel safety, since the need for fire management personnel to make a direct attack on a wildfire is greatly reduced.

Counterfiring from within a constructed fireline.

DESCON has another big advantage in that planning can be done ahead of time for many wildland areas. Fire maps can be made up with known DESCON features marked right on them for use in both planning possible future fire management operations and continuing ongoing fire management operations. Fire management personnel who are going to be involved in either use of DESCON should be well versed in both the fuels and topography that they will be working with.

DESCON can also be very effective when utilized in fire management operations involving fragile environmental areas, such as high alpine or tundra fires, where normal fire management operations can cause more environmental damage than the fire itself. In this type of a situation, either through advance planning or on-the-scene planning, the fire is allowed to burn out when it reaches either a constructed, or, more normally, a natural barrier that can either be used "as is" or improved through counterfiring.■

Estimating Fuel Moisture in the Northeast: Fuel Sticks Versus TI–59

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Fuel moisture content is an important factor in the calculation of several indexes that are part of the National Fire Danger Rating System (NFDRS) (*2*). The amount of moisture in a fuel particle and the rate at which it dries are controlled by particle size (diameter) and by environmental parameters including temperature; relative humidity; wind speed; solar radiation received by the particle; and the amount, duration, and time since last precipitation. Before a particle can burn, excess moisture must be evaporated to allow gases to be liberated and ignited.

The NFDRS uses fuel moisture to predict fire occurrence and behavior. NFDRS indexes that depend upon fuel moisture include the burning index (BI), which estimates the flame length of a spreading flame front; the ignition component (IC), which predicts the probability of a firebrand igniting a fire that will require suppression action; and the spread component (SC), which estimates the rate of spread of a flame front. Fuel moisture sticks are commonly used to measure fuel moisture content. The fuel sticks consist of four 1/2-inch-diameter wooden dowels that, together, weigh 100 grams oven-dried. The fuel sticks are placed over a bed of conifer needles in an exposed area and weighed daily. The weight in excess of 100 grams can be expressed directly as the moisture content of woody fuels one-fourth to one-half of an inch in diameter (commonly referred to as 10-hour timelag fuels).

In 1979, an algorithm was developed so that the TI–59 hand-held calculator could be used to estimate fuel moisture content (*1*). The TI–59 uses daily weather observations such as precipitation duration, relative humidity, and air temperature to estimate weight of the fuel sticks.

In 1982, the Massachusetts Bureau of Fire Control (BFC) adopted the 1978 NFDRS as its method for monitoring fire weather and predicting fire behavior and occurrence. Most fires in Massachusetts occur in early spring after the snow has melted but before plant growth resumes (March, April, and early May). It is during these months that fuel moisture contents are typically at their lowest levels. In 1983 the BFC fire-weather station at Amherst, MA, weighed fuel sticks and estimated values using a TI–59 hand-held calculator. In this study estimates of BI, IC, and SC obtained using fuelstick values are contrasted with values obtained using the TI–59 estimates of fuel moisture.

Methods

Fire weather data covering a 56-day period during the spring of 1983 were used. Fuel moisture content, BI, IC, and SC were calculated using data derived from fuel sticks and the TI–59 calculator. The average values based on fuelstick and TI–59 estimates of fuel moisture were compared using Students t-test. We used regression analysis to compare fuel stick weights and TI–59 estimates of fuel moisture (*3*).

Results

Estimates of fuel moisture based upon TI–59 calculations were consistently lower than those measured by fuel sticks (figure 1). On days when it was raining when the fuel sticks were weighed, excess water on the fuel sticks may have given anomalously high values. Because the TI–59 algorithm does not return a fuel stick value larger than 35 percent, we decided to eliminate rain days from the analysis. Differences between values calculated using the TI–59 estimate of fuel moisture and those obtained from the fuel sticks were highly significant (P less than .001) for MC, BI, and IC (table 1). The fuel sticks consistently gave higher values on days following storms. Differences between values derived using the two methods of estimating fuel moisture gradually decreased in the days following storms, suggesting that the moisture content of the fuel sticks approached equilibrium with the environment more slowly than predicted by the TI–59 (table 2).

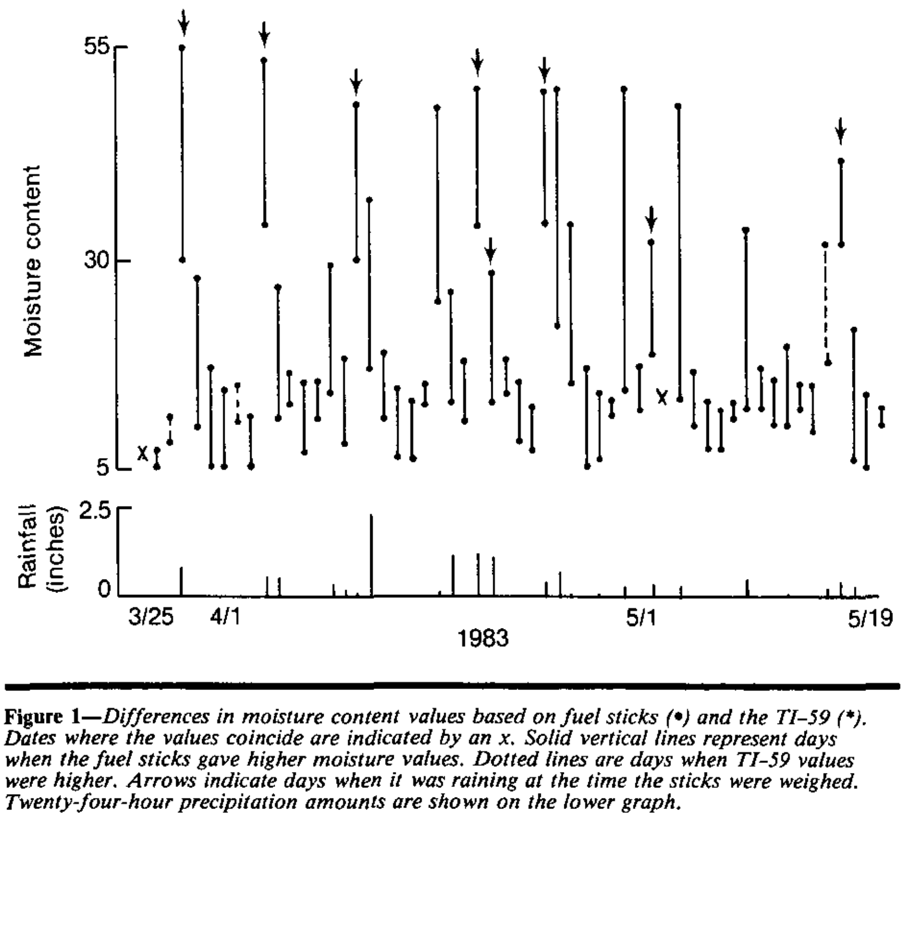

Figure 1—*Differences in moisture content values based on fuel sticks (•) and the TI-59 (*). Dates where the values coincide are indicated by an x. Solid vertical lines represent days when the fuel sticks gave higher moisture values. Dotted lines are days when TI-59 values were higher. Arrows indicate days when it was raining at the time the sticks were weighed. Twenty-four-hour precipitation amounts are shown on the lower graph.*

Table 1—*Average values for moisture content (MC), burning index (BI), ignition component (IC), and spread component (SC) based upon measured and TI-59 estimates of 10-hr timelag fuel moisture [values are for days when it was not raining at the basic observation time (1300 EST)]*

Parameter	Average based on Fuel sticks	Average based on TI-59	P value
MC	20	10	<.001
BI	26	31	<.001
IC	15	22	<.001
SC	8.6	9.5	.06

Fuel stick and TI-59 moisture contents were also compared by regression analysis (figure 2). The correlation coefficient (r) indicates a positive relationship between the two sets of values (as would be expected), but the coefficient of determination (r^2) indicates that only about half of the variation in fuel stick data is explained by the TI-59. Thus, there is a wide range of actual fuel moisture values associated with each TI-59 estimate. The variability evident in figure 2 indicates that in the Northeast it may be difficult to derive an algorithm to relate fuel moisture to weather variables using hand-held calculators like the TI-59.

Differences in predicted fuel moisture influenced calculations of burning indexes, ignition components, and spread components. Because the TI-59 "dried out" the fuel more rapidly than the fuel sticks actually dried, BI's, IC's, and SC's rose more quickly and to higher levels in the days following precipitation. Overall, the TI-59 gave values for the BI's and IC's that were significantly higher than those derived using fuel stick data (table 1). For the SC, differences between the two values were not significant.

Discussion

Predictions of NFDRS indexes depend upon the accuracy of input values used in the calculations. Fuel moisture content is one of the

Table 2—*Average difference in moisture content (MC), burning index (BI), ignition component (IC), and spread component (SC) between fuel-stick and TI-59 values on days following precipitation*

Days since precipitation	Number of observations	Average difference			
		MC	BI	IC	SC
0	8	19	−3	−1	−0.5
1	7	15	−12	−8	−2.9
2	7	13	−6	−7	−3.3
3	7	8	−2	−8	1
4	6	4	−6	−4	3.4

most important values used to estimate fire occurrence and behavior. If the fuel moisture values used for the NFDRS do not represent field conditions, then the indexes cannot properly rate fire danger.

Our analysis shows that the TI-59 does not reliably predict fuel moisture content in central Massachusetts. Differences are greatest during and following storms, when the TI-59 can underestimate fuel moisture by more than 30 percent. In the Northeast, spring storms are often followed by periods of cool temperatures and high humidity. Fuel sticks dry more slowly than predicted by the TI-59, leading to anomalously high predictions for burning indexes and ignition components. Bureau of Fire Control personnel often complained to us that their estimates of fire danger, which were based upon TI-59 calculations of fuel moisture, were too high. The TI-59 often predicted moderate to high fire danger, for 2 to 3 days following storms, but BFC personnel knew from years of experience that the actual fire danger was low. Low fire occurrence on those days tended to support the beliefs of BFC personnel. Eventually this discrepancy resulted in a lack of faith in the NFDRS on the part of BFC personnel.

We have recommended that BFC use fuel sticks rather than the TI-59 to estimate fuel moisture in Massachusetts.

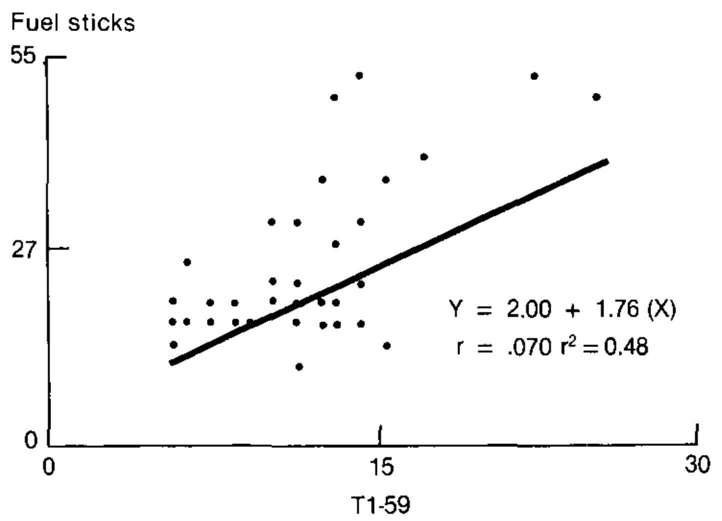

Figure 2—*Fuel moisture values based upon the TI-59 plotted against those derived from the fuel sticks. The solid line indicates the regression line. The analysis is based upon 46 pairs of data. We excluded from our analysis those days when it was raining.* ■

Literature Cited

1. Burgan, R. E. Fire danger/fire behavior computations with the Texas Instruments TI-59 calculators: user's manual. Gen. Tech. Rep. INT-61. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 25 p.
2. Deeming, J. E.; Burgan, R. E.; Cohen, J. D. The national fire danger rating system. Gen. Tech. Rep. INT-39. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 63p.
3. Snedecor, G. W.; Cochran, W. G. Statistical methods. 7th ed. Ames, IA: The Iowa State University Press; 1980. 507 p.

Prescribed Burning of a Chained Redberry Juniper Community With a Helitorch [1]

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Prescribed burning is an effective means of reducing downed woody debris in redberry juniper (*Juniperus pinchotii*)-mixed grass communities. Conventional ground ignition techniques are effective and relatively inexpensive, but they are limited to accessible areas. Large areas of rough terrain cannot be burned in a single day using ground ignition methods. This paper describes a prescribed fire conducted on a large area with a helitorch.

The 4,015-hectare (9,914-acre) unit is dominated by redberry juniper-mixed grass habitat characteristic of the Texas rolling plains. It is located on the 7L division of the Triangle Ranch 40 kilometers (24 miles) northeast of Paducah, TX. (latitude 34°10′ N, longitude 100°00′ W).

The unit was chained 2 years prior to burning. Red needles were present on the chained juniper at the time of burning. Fine fuel bed was composed primarily of tobosagrass (*Hilaria mutica*), little bluestem (*Schizachyrium scoparium*), sideoats gramma (*Bouteloua curtipendula*), vine mesquite (*Panicum obtusum*), buffalograss (*Buchloe dactyloides*), and threeawns (*Aristida spp.*).

As a result of light grazing pressure (40 acres/animal unit/year), most grass plants were not grazed, leaving an abundance of rank material that reduced the palatability of forage. Chained woody debris impaired livestock handling and decreased forage availability and accessibility. Furthermore, seedlings and basal sprouts of redberry juniper and honey mesquite (*Prosopis glandulosa*) were present on the unit.

Objectives

The specific burn objectives were to:

- Remove 80 percent of downed woody debris.
- Reduce juniper canopy cover by 70 percent.
- Remove decadent material from 70 percent of grass plants.
- Check encroachment of juniper and mesquite by killing 70 percent of young plants.

The last two objectives would be met if fire carried over 70 percent of the unit. Rank growth of herbaceous plants is removed by burning and juniper, and mesquite trees are killed if burned at a young age. Juniper trees can be killed if less than 15 years old (*4*), and honey mesquite can be killed if less than 2.5 years old (*7*).

Methods

The effectiveness of the burn in removing downed woody debris and reducing canopy cover was measured along five 30-meter (98-foot) permanent transects randomly located in the unit. In addition, 20 temporary sampling planes were established. Permanent transects were marked with 1-meter (3-foot) lengths of concrete reinforcement bar numbered with metal livestock ear tags. Downed woody debris along transects was inventoried using a planar-intercept technique (*1*). Canopy cover of all shrubs was estimated using line intercept (*2*).

After burning, inventory of woody debris and canopy cover was repeated on permanent transects and on an additional 20 temporary transects. For each transect, percent consumption of woody debris was calculated according to Brown (*1*). Reduction of canopy cover was determined by:

$$\text{Percent reduction} = \left(1 - \frac{\text{postburn cover}}{\text{preburn cover}}\right) \times 100 \text{ percent}$$

To test the efficiency of permanent sampling, t-tests were conducted on all attributes measured.

Burning Strategy

The unit was prepared and burned according to Wright and Bailey (*6*). Two firelines were dozed 120 meters (400 feet) apart on the north and east sides of each

[1] The authors wish to thank Henry A. Wright and Clifton M. Britton of Texas Tech University, Jimmy Propst and Gene Bradbury of Propst Helicopters, and Zach Osburn of Triangle Ranch. Many students and staff members from Texas Tech helped on this burn. Their assistance is greatly appreciated.

unit. Eighteen kilometers (11 miles) of fire line were burned out with strip headfires in January and February of 1985 under cool conditions (relative humidity 40 to 60 percent, temperature 4 to 16 °C (40 to 60 °F), and windspeed 0 to 16 kilometers per hour (0 to 10 mi/h)). Main unit headfires were lit with a helitorch on 2 days, February 25 and March 6, 1985. Weather conditions were measured every 30 minutes with a belt weather kit (*5*).

Aerial ignition was selected for safety and time considerations. Steep, dissected terrain made hand ignition unsafe. Sheer drops of 20 to 30 meters (65 to 100 feet) were common. Fine fuel load in drainages was about 10,000 kilograms per hectare (9,000 lb/acre). The unit was dissected by numerous fuel discontinuities in the form of roads, streams, and rocky ridges. A strip headfire ignition pattern starting in the northeast corner and moving southwest into the wind was used to ignite the unit. Strip spacing was 100 to 150 meters (300 to 450 ft). Consequently, an estimated 480 kilometers (300 mi) of strip headfires were needed to burn the unit. Hand ignition would have required at least 600 work hours, not including time for holding crews. By contrast, 70 work hours were required for aerial ignition.

Ignition fuel was a mixture of Alumagel and unleaded gasoline. The amount of Alumagel used varied according to air temperature and relative humidity; cool and moist conditions required more Alumagel. With an air temperature of 21 °C (69 °F) and relative humidity of 34 percent, 5.6 kilograms (12.3 lb) of Alumagel were mixed with 190 liters (50 gal) of gasoline. With an air temperature of 15 °C (59 °F) and relative humidity of 45 percent, 6.0 kilograms (13.2 lb) of Alumagel were required to obtain the desired consistency. The fuel mixture was applied at an average speed of 65 kilometers per hour (40 mi/h) from a height of 45 to 60 meters (150 to 200 ft). The mixture was dropped in a 5-meter-wide (15 feet) strip, each drop the size of a golf ball.

Personnel and equipment were the same both days. A burn boss, aerial ignition boss, 5-person helipad crew, and two 6-person holding crews were used. The unit could not be seen in its entirety from a single observation point. Therefore, the aerial ignition boss directed ignition from the helicopter. The burn boss, located on the best possible ground observation point, directed the activities of ground personnel and coordinated ground-to-air communication. Two radio frequencies were used—one for the burn boss, helicopter, and helipad boss and another for the burn boss and holding crews.

Aerial ignition of chained redberry juniper using a helitorch.

Results

Ignition of the unit was completed in about 10 hours. The first day, air temperature ranged from

17 to 21 °C (63 to 69 °F), relative humidity ranged from 30 to 40 percent, and windspeed was 16 kilometers per hour (10 mi/h). After a week of undesirable weather, burning was completed on a cooler day (temperature 12 to 15 °C (54 to 59 °F), relative humidity 40 to 50 percent, and windspeed 13 kilometers per hour (8 mi/h)). Containment of the fire was not a problem, and no suppression actions were required. Conditions for burning on March 6 were cooler than normally prescribed for this fuel type. Early spring green-up, leading to a rapidly increasing green component in the fuel bed, forced ignition on a relatively cool day. As a result, the specific burn objectives were not met on the area burned March 6.

From transects flown after completion of ignition, it was determined that 61 percent of the unit burned. Concentration of livestock on ridges and low-lying flat areas reduced continuous fine fuel below 1,000 pounds per acre and created fuel breaks. By comparison, drainages and hillsides were not heavily grazed. As a result, only 20 to 30 percent of the areas of greatest livestock concentration were burned. However, dissected terrain was characterized by 80 to 90 percent fire coverage.

The accompanying table summarizes reduction in woody fuel volume and canopy cover. Results from permanent and temporary transects were similar for all attributes measured. Downed woody fuel and total canopy cover were reduced only 50 and 44 percent respectively, primarily due to the discontinuous nature of the fire. Where fine fuel was continuous enough to ensure fire spread, woody fuel volume was reduced 90 percent, and total canopy cover was reduced 85 percent. Moreover, consumption of 54 percent of live tree canopy reduced juniper stature. In addition to improving visibility across the pasture, this reduction in plant stature will reduce the competitive ability of juniper, thereby increasing production of herbaceous species. Cooler than normal conditions, coupled with light fuel loads in some areas produced less than desired results on the second day of ignition.

Total cost of burning the unit was $22,439.97, or $5.59 per hectare ($2.26/ac). The helitorch was contracted for $2.47 per hectare ($1.00/ac). Remaining costs were primarily attributed to personnel ($6,150) and transportation ($3,996).

Table 1—*Downed woody fuel and canopy cover reduction resulting from a spring prescribed fire in the Texas rolling plains*

	Transects					
	Permanent [1]		Temporary [2]		Total [3]	
Attribute	Mean	Standard error [4]	Mean	Standard error	Mean	Standard error
Preburn woody fuel (m^3/ha)	16.8	5.0	20.1	4.1	19.4	3.4
Postburn woody fuel (m^3/ha)	10.9	5.8	9.4	2.4	9.7	2.2
Woody fuel reduction (%)	35.1		53.2		50.0	
Preburn canopy cover (%)						
Downed woody debris	12.6	4.0	12.8	1.8	12.8	1.6
Redberry juniper	15.1	3.0	13.0	1.3	13.4	1.2
Other shrub species	2.7	1.7	3.1	0.8	3.0	.7
Total	30.4	6.0	28.9	2.6	29.2	2.3
Postburn canopy cover (%)						
Downed woody debris	7.5	2.1	8.2	1.2	8.1	1.0
Redberry juniper	6.0	2.5	6.2	1.6	6.2	1.3
Other shrub species	2.3	1.5	2.2	.7	2.3	.6
Total	15.8	3.9	16.7	2.2	16.5	1.9
Canopy cover reduction (%)						
Downed woody debris	40.4		35.9		36.7	
Redberry juniper	60.2		52.3		53.7	
Other shrub species	14.8		29.0		23.3	
Total	48.0		42.2		43.5	

[1] n = 5
[2] n = 20
[3] n = 25 (combined results from all transects)
[4] standard error of the mean calculated according to Steele and Torrie (1980)

Management Implications

Near optimal weather conditions on February 25 compensated for fine fuel inadequacies, and burn objectives were achieved. Because of cooler weather conditions and increased percentage of green fine fuel on March 6, overall objectives were not met. In light of this burn, we believe large units can be burned safely and quickly with a helitorch at far less expense than hand ignition. Because of the speed of the operation, communication is of fundamental importance when using aerial ignition. Our experience indicates that two radio frequencies are desirable to minimize confusion.

Permanent and temporary transect means were not significantly different ($P < 0.01$) for any of the attributes measured. Therefore, these data indicate that fewer transects can be used for sampling downed woody debris and shrub canopy cover in this fuel type if transects are permanently established. Permanent sampling planes can be established almost as quickly as temporary transects in the field. The increased sampling efficiency offered by permanent transects indicates that they are a viable alternative to temporary transects in this fuel type. However, additional research is needed before permanent transects can be universally recommended.

Literature Cited

1. Brown, J.K. Handbook for inventorying downed woody material. Gen. Tech. Rep. INT-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1974. 24 p.
2. Canfield, R.H. Application of the line interception method in sampling range vegetation. Journal of Forestry. 39: 388-394; 1941.
3. Steele, R.G.D.; Torrie, J.H. Principles and procedures of statistics. 2nd ed. New York: McGraw-Hill; 1980.
4. Steuter, A.A.; Britton, C.M. Fire-induced mortality of redberry juniper (*Juniperus pinchotii* Sudw.). Journal of Range Management. 36: 343-345; 1983.
5. U.S. Department of Agriculture, Forest Service. Belt weather kit. Fire Control Notes. 20(4): 122-123; 1959.
6. Wright, H.A.; Bailey, A.W. Fire ecology. New York: John Wiley and Sons; 1982.
7. Wright, H.A.; Bunting, S.C.; Neuenschwander, L.F. Effect of fire on honey mesquite. Journal of Range Management. 29: 467-471; 1976. ■

Efficient Fire Management

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Current Forest Service policy on wildland fire suppression is to suppress wildfires at a minimum cost consistent with fire management direction and land and resource management objectives. Each wildfire ignition requires an appropriate suppression response. The Forest Service defines an appropriate response as a "timely action with appropriate forces to safely achieve fire suppression objectives."

Now what does that mean? It means we should select the response that meets the criteria of the policy and resource management objectives without wasting precious dollars. According to the Forest Service Manual, there are basically three appropriate responses to choose from—confine, contain, or control:

Confine—To limit fire spread within a predetermined area principally by the use of natural or preconstructed barriers or environmental conditions. Suppression action may be minimal and limited to surveillance under appropriate conditions.

Contain—To surround a fire, and any spot fires therefrom, with control line, as needed, which can reasonably be expected to check the fire's spread under prevailing and predicted conditions.

Control—To complete control line around a fire, any spot fires therefrom, and any interior islands to be saved; to burn out any unburned area adjacent to the fire side of control line; and to cool down all hot spots that are immediate threats to the control line until the line can reasonably be expected to hold under foreseeable conditions.

In the past, the Forest Service has tended to emphasize fire suppression. Therefore, the action the public is most familiar with is "control." Also, the fires requiring this kind of action are the ones most likely to get national press coverage.

The action I want to talk about here is "confine." To implement this action smartly requires considerable expertise, quick and decisive planning, and a degree of calculated risk. One forest that has taken the risk in full view of the public is the Coronado National Forest, headquartered in Tucson, AZ. Although 1985 was not an exceptionally active fire season for the Coronado Forest, it was at least an average season, well above the national average as far as both the number of fires and acres involved.

On 9,610 acres of wildland fires on the Coronado, the selected response was to confine the fire. Now that in itself is quite an accomplishment, particularly in light of the fact that more than 500 of those acres were four fires burning at the same time, in full view of Tucson and less than 1 mile above expensive homes adjacent to the Coronado boundary. Forest managers decided that the fire spread would be limited only by natural barriers and environmental conditions, and that surveillance would be the appropriate action.

Now, consider taking that risk with an entire metropolitan population watching to see if you did the right thing. I don't intend to say we had no problems, but it was quite an accomplishment and an important step. To coordinate the action and keep the public informed, to reassure worried homeowners, to keep emergency 911 numbers unjammed, and so forth was not an easy task. The decision process itself is perhaps the biggest stumbling block. That initial decision is what starts it all.

The selected response to confine a fire could be made based on natural barriers or environmental conditions. These two factors were the primary basis for selection in the case of the Coronado National Forest. If a fire is burning toward a large rockpile and will then go out, the decision seems easy. But maybe it is not so easy. If you don't go all out, use engines, airtankers, and the like, and if the fire doesn't go out, what then?

I do feel that unfortunately the budget is a major factor in deciding on the level of action. The more you can do with less, it seems the more you are asked to do, and the ones that waste more get more to waste.

The Coronado National Forest has outlined some things over several years that have helped the manager on the ground make quick and sound decisions in difficult situations. An analysis of pertinent factors, similar to an economic analysis, supports the decision to select a particular suppression response. Standard fire behavior items such as intensity, fuel type, and fuel impostures, and the like, are coupled with resource values at risk to determine the cost/benefit value of any action.

The Coronado National Forest has been divided into basically two zones. Zone 1 has higher resource values, and zone 2 has lower values. Any risk to life and property demands the same aggressive suppression action in both zones. In addition to these two zones there are eight wilderness areas that receive varying suppression responses. The initial decision is based on the following:

- Where is the fire burning now?
- Where is it expected to go?
- What are the resource values at risk?
- Does the fire intensity level fit in with the land management objectives for this area?

Basically, ask yourself, "Is the fire creating unacceptable resource damage or is it expected to do so before natural barriers or environment factors limit the spread?" District fire management officers (FMO), with the help of fire behavior calculations and several years of experience in local fire effects, can answer this question fairly rapidly. Notice that I've emphasized some broad general descriptions and no "magic numbers." That's because there are no magic numbers. If you rely on absolute formulas, you cease to think. On the Coronado National Forest, we knew from past experience that the particular fires we were facing, under these conditions, were not going to create unacceptable resource damage.

You're probably sitting there thinking "that must take hours." But the initial decision by the district FMO took only minutes from the report of smoke and was reviewed from the air by the forest FMO within the hour. The suppression action, to confine, was quick and very sound. With proper planning, both short and long range, these initial action decisions can be very quick. All it requires is someone willing to take the risk based on the best information available. The employees of the Coronado National Forest are to be commended for their initiative.

Confinement fires on the Coronado National Forest for January-August 1985

Fire name	Ranger district	Size (acres)
McDonald	Douglas	80
Redhill	Douglas	1500
Stanford	Douglas	75
South	Douglas	300
Leslie	Douglas	200
Castle	Safford	25
East Divide	Safford	120
Windmill	Safford	800
Ash	Safford	240
Veach	Safford	1214
Montana	Nogales	3700
Hells Gate	Nogales	300
Williams	Sierra Vista	300
Peak	Sierra Vista	10
Soldier	Santa Catalina	430
Espero	Santa Catalina	125
Finger	Santa Catalina	110
Pima	Santa Catalina	80
Cathedral	Santa Catalina	10
Total		9610

Using the Fire Load Index as A Class-Day Indicator

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Introduction

One of the major presuppression problems that wildfire management personnel have to deal with is deciding the type and quantity of firefighting personnel and equipment to bring on line in accordance with the class-day indicator. Since the 1978 revision of the National Fire Danger Rating System (NFDRS), the fire load index (FLI) has assumed a prominent role as a class-day indicator, in addition to the burning index (BI), and in many cases it will probably replace the BI as the primary class-day indicator.

Index Comparison

The burning index utilizes three major factors or components as its regulators: The 1-hr timelag fuel moisture (1-hr TL), the spread component, and the energy release component (ERC). Although this particular index provides a good indicator as to the anticipated fire behavior (such as rate of spread, fireline intensity, and flame length), it does not take into consideration the cause of the fires. However, fire cause plays a major role in determining how many fires can be expected on any given day. The number of fires expected on a given day in turn plays a major role in determining the number of personnel and the amount of equipment needed to contain the fires that occur.

The fire load index (FLI), which is a rating of the maximum effort required to contain all probable fires occurring within a rating area during the rating period, is not based only on the three major factors or components that regulate the BI. It is also the result of calculations that include the BI itself, the ignition component or IC (a rating of the probability that a firebrand will cause a fire requiring suppression action), the lightning fire occurrence index or LOI (a numerical rating of the potential occurrence of lightning-caused fires), and the human-caused fire occurrence index (an indication of the expected number of human-produced firebrands capable of starting fires that a rating area will be exposed to during the rating period).

Nevertheless, the BI, as well as the other regulators that are used to determine the FLI, should still be considered the primary indicators in determining the type of equipment needed and the distribution of fire suppression personnel. These indexes are still the primary indicators of the type of fire behavior to be expected during the relevant rating period.

Fire Data Compilation and Comparison

The following is a compilation and comparison of the fires that occurred within one National Park Service area during a 5-year period. These data *do not include* several large fires (in excess of 200 acres) that have occurred because such large fires are the exception rather than the rule. Data collected prior to 1978 have not been included because the NFDRS was revised in 1978. Fire weather data prior to that date were based on the old NFDRS system, which was shown to be unsatisfactory.

Table 1—*Number of fires occurring within various ranges of FLI*

FLI	Number of fires	FLI	Number of fires
0–2	21	51–53	5
3–5	4	54–56	0
6–8	3	57–59	2
9–11	4	60–62	0
12–14	4	63–65	0
15–17	3	66–68	0
18–20	8	69–71	0
21–23	2	72–74	2
24–26	10	75–77	0
27–29	12	78–80	0
30–32	19	81–83	0
33–35	19	84–86	0
36–38	14	87–89	0
39–41	23	90–92	0
42–44	12	93–95	0
45–47	4	96–98	0
48–50	14	99–100	0

Table 2—*FLI versus percent of fires occurring within given FLI limits*

FLI	Fires occurring within index limits	Fires occurring within index limits expressed as percent of total
0–17	39	21
18–26	20	11
27–38	64	35
39–44	35	19
45–100	25	14

Table 3—*FLI versus percent of times FLI occurred*

FLI	Times FLI occurred	Times FLI occurred expressed as percent of total FLI days
0–17	1,113	74
18–26	191	13
27–38	126	8
39–44	42	3
45–100	29	2

Table 4—*Percentage of times FLI occurred and percentage of fires occurring within FLI limits*

FLI	Times FLI occurred (% of total FLI days)	Fires occurring within FLI limits (% of total)
0–17	74	21
18–26	13	11
27–38	8	35
39–44	3	19
45–100	2	14

Table 5—*FLI vs average size of fire occurring within FLI limits* [1]

FLI	Size range of fires within FLI	Average size of fire (acres)
0–17	0–10	2
18–26	0.25–15	3
27–38	0–60	5
39–44	0.1–130	10
45–100	0.25–45	9

[1] Data do not include any unusually large fires (more than 200 acres) that occurred.

Table 6—*Comparison of FLI, class-day rating system, and readiness class*

FLI	Class day	Readiness class
0–17	Low	I
18–26	Moderate	II
27–38	High	III
39–44	Very high	IV
45–100	Extreme	V

Each readiness class calls for a different step-up action, with the intensity of the various step-actions increasing as the readiness class increases. For example, in a readiness class I situation, the step-up action might include a normal 8-hour tour of duty, with a minimum of two initial attack personnel per district, and a maximum of four initial attack personnel per district. In a readiness class IV situation, the step-up action might consist of the following directives: "All initial attack personnel on 7-day workweek, with all tours of duty to be extended from 0800 to at least 1800 hours. At least one brush truck to be on patrol in each subdistrict at all times during the day shift."

Conclusion

Personnel currently using the BI as the primary class-day indicator might want to give the FLI a second look. From all present indications, the FLI seems to surpass the BI as a class-day indicator in terms of both accurateness and inclusiveness.

Those not using any class-day indicators might want to consider the FLI. However, in order to effectively use either the BI or the FLI as a class-day indicator, it is necessary to have the following items:

1. At least 3-5 years of past fire weather records.
2. At least 3-5 years of past fire occurrence records.

Personnel who do not maintain their own fire weather stations and records might be able to obtain sufficient correlatable data from nearby State and National Parks and State and National Forests. ■

Evaluating Structural Damage From Wildland Fires [1]

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Damage to structures as a result of wildfires increases each year as urban development continues to encroach into wildlands. The need for data on these losses increases correspondingly, as fire managers seek better information to use in their fire management planning. However, information on wildfire damage is often difficult to find. In the past, natural resource losses were emphasized, and structural fire suppression was not considered a basic Forest Service responsibility. Thus, little attention was paid to the amount and value of structural losses from wildfires.

To determine how the availability and utility of data on structural losses might be improved, we examined the literature and valuation reports from both public and private fire and insurance organizations. Our analysis was limited to southern California, because efforts to locate data on other potential target areas for large structural losses were unsuccessful in the time available. Even in southern California, available data sources were often incomplete. Furthermore, because various methods are used to gather data, reports from different agencies on the same losses tend to be inconsistent. For a serious fire, assessor records on property losses were compared with various other types of property loss information, including data gathered by an appraisal team.

Results for the case studied showed that the loss estimated by the appraisal team was higher than that obtained by other methods. The results also showed that property tax records could provide a convenient source for structural loss data. Several recommendations are offered for the collection and analysis of data on property losses due to wildfires.

Data Sources

We encountered major problems in our search for data. Although we identified a variety of data sources, reports were difficult to acquire. Some reports from past fires could not be located, whereas many from more recent fires were incomplete. Names and dates did not correspond among reports from different agencies. Numbers of structures lost also differed among agencies due to aggregation of related buildings, such as barns and storage facilities.

To evaluate the sources of data and their usefulness, we developed a method for rating major desirable characteristics of the data (table 1). Rated characteristics were accessibility, extent of documentation (based on fire damage level), reliability, verifiability, and inclusion of data on fire behavior. Three ratings were used: very useful, useful, and not useful. A useful rating implies that the data obtained are helpful in certain specific circumstances, but that the source listed is not consistently satisfactory for each characteristic. Some data sources could not be rated because the source did not include given categories.

Our review of data showed that the methods most often used to estimate the value of structures lost in wildfires were either appraisal by a team or individual or determination of market value, replacement cost, or valuation by the local assessor. When values are adjusted for assessor practices, inflation, and local market conditions, they should not differ noticeably among sources.

Local tax rolls provided information on the value of property assessed at legally mandated intervals. One of the problems usually associated with the tax assessment is that it does not reflect current market value (Lynn 1969). In California, this problem has been mitigated by the adoption of a tax limitation initiative (Proposition

[1] This article summarizes work accomplished under a cooperative agreement between the University of California, Riverside, and the Pacific Southwest Forest and Range Experiment Station. The complete final report is on file at the Pacific Southwest Forest and Range Experiment Station, 4955 Canyon Crest Drive, Riverside, CA 92507: Frost, Grant; Gardner, Philip D. Validating estimates of structural damages resulting from wildland fires. Technical Completion Report; June 1982.

Table 1—*Descriptive evaluation of data on structural losses from wildfires in southern California, by source* [1]

Source	Accessibility	Availability (based on number of structures per fire)		Data on fire behavior	Reliability	Verifiability
Federal:		≥100	<100			
USDA Forest Service	+	+	–	–	0	–
State (California):						
Department of Forestry	+	+	0	–	0	+
Department of Insurance	+	N/A	N/A	N/A	0	N/A
Fire marshal	+	0	0	–	0	0
Local:						
Assessor	0	+	0	N/A	+	+
Fire department	0	+	0	–	0	+
Engineer, building department	+	+	N/A	N/A	+	+
Private:						
Board of realtors	–	N/A	N/A	N/A	?	N/A
Insurance companies	–	N/A	N/A	N/A	0	N/A
Data collection agencies	+	0	–	N/A	?	N/A

[1] +, very useful; 0, useful; –, not useful; N/A, not applicable; ?, unknown.

13), and the assessed value must reflect the value of the structure at the time of sale. Assessed value can be adjusted to current prices by accounting for changes in local market prices and inflation from the base year (the year the property was last sold). Nonuniformity between taxing districts has also been minimized under the initiative. In other States, however, careful attention must be given to how the assessor appraises property and to possible nonconformity in practices across districts.

Case Study

To find a method that could reasonably provide the value of a damaged or destroyed structure, we obtained and analyzed data for a case study, the Panorama fire. It burned about 340 structures in or near San Bernardino, CA, in November of 1980. The Forest Service Pacific Southwest Region and the California Department of Forestry put together a professional appraisal team to determine the extent of structural damage. The appraisal team's report and property tax records from the county assessor contained enough information to allow comparison of several real property valuation methods. As the buildings destroyed were in a fairly homogeneous residential area, we randomly selected a 10-percent sample of all the residences destroyed and estimated these five values: replacement cost, replacement cost less depreciation, market value, property assessment, and appraisal estimate. Each estimated value was statistically analyzed and compared with the others.

Adequacy of the sample size was tested by increasing it by units of 10 homes and calculating the difference in the mean property values (old versus new). The mean did not change significantly after the addition of 30 homes, which suggested that the 10-percent sample was representative of the entire population.

Total damage estimated for the sample by the five methods ranged from a high of $2.5 million to a low of $1.7 million. Average difference per structure was about $25,000 between the high and low estimates (table 2). Statistical examination of data for individual parcels showed that the market value estimates, although lower, correlated well with the two replacement cost values (table 3). The differences might be explained partly by the 2- to 10-month lag for the assessor to obtain sale prices and to make the necessary adjustments in market values. Market prices tend to lag behind, whereas replacement costs are updated regularly by a computer program.

Property assessment was highly correlated with replacement cost less depreciation, replacement cost, and market value. When assessed value figures were adjusted for annual housing price increases, the resultant values were comparable to replacement cost less depreciation and fell between market value and replacement cost figures (table 2). The independent appraisal estimates were poorly correlated with the others partly because the values tended to be categorized in a few limited value classes, such as $100,000, $80,000, and $60,000. The average home value estimated by the appraisal team was higher than that estimated by other methods.

Table 2—*Total and mean damage values for 34 structures (10-percent sample) destroyed in the Panorama fire, near San Bernardino, CA, November 1980*

Real property value	Total damage	Mean damage per structure	Standard deviation
Appraisal estimate	$2,560,000	$75,000	$15,200
Property assessment	2,000,000	59,000	12,800
Market value	1,730,000	51,000	8,500
Replacement cost	2,500,000	73,000	14,000
Replacement cost less depreciation	2,240,000	66,000	13,300

Table 3—*Sample correlation coefficients among real property values for 34 structures (10-percent sample) destroyed in the Panorama fire* [1]

Real property value	Appraisal estimate	Property assessment	Market value	Replacement cost	Replacement cost less depreciation
Appraisal estimate	—				
Property assessment	.42 (.10, .66)	—			
Market value	.51 (21, .72)	.75 (.55, .87)	—		
Replacement cost	.41 (.08, .66)	.76 (.57, .87)	.95 (.90, .97)	—	
Replacement cost less depreciation	.43 (.11, .67)	.79 (.62, .89)	.94 (.88, .97)	.99 (.98, 1.00)	—

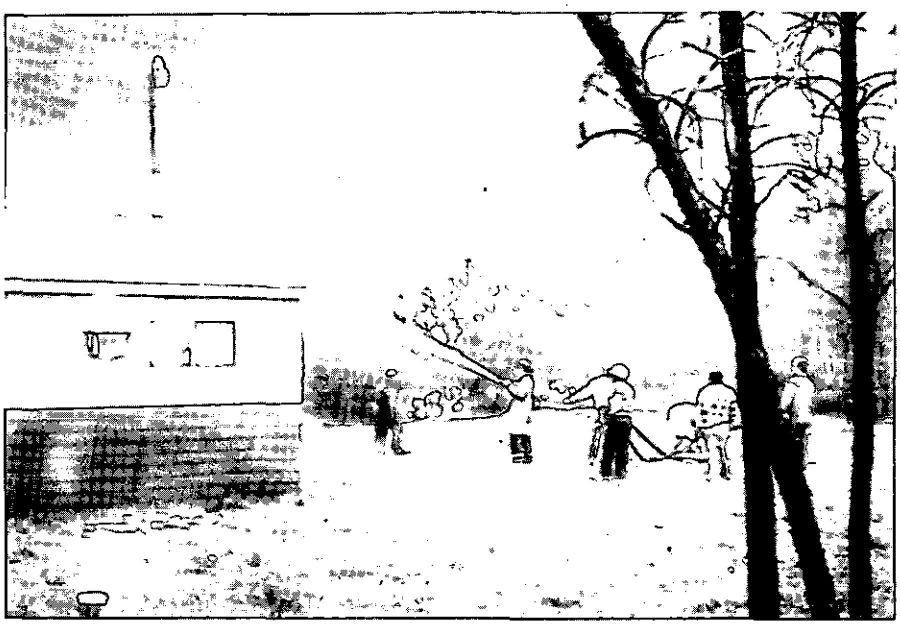
[1] Numbers in parentheses are the approximate 95-percent confidence intervals for the population correlation coefficients.

Recommendations

Even though several data sources were accessible, the information they contained could not be verified. Data on the number and value of structures lost in a fire were inconsistent among agencies. In our judgment, the local assessor's rolls apparently could provide easy access to value information on structures damaged or destroyed by fire in California. Adoption of this approach in other States may be more difficult.

To obtain information on the type of a structure and its value from assessor records, the firefighting agency has only to report accurately the address of a structure. Therefore, firefighting agencies will need to establish a common set of clear guidelines and definitions on how to account for and accurately report the address of different types of structures, and will need to coordinate closely with local assessors.

The degree of data precision required for fire management purposes must be determined for each situation. Nevertheless, accurate notes on some basic information



Structural damage from wildfires increases every year as more and more development takes place in wildland areas.

will undoubtedly be valuable on any fire report. Precise geographic information (parcel number or street address) should be recorded for each structure. In addition to geographic location and fire characteristics, some information on structural characteristics may be desirable. Such variables as type of structure, quality, square footage, and improvements may be helpful to adjust values taken from property assessment rolls. ■

Literature Cited

Lynn, Arthur D., ed. The property tax and its administration. Madison, WI: University of Wisconsin Press; 1969. 244 p.

The Evolution of National Park Service Fire Policy [1]

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Abstract: Fire policy depends upon the function served by a unit of land and the land manager's perception of society's attitudes toward the role of fire in national parks containing large natural areas. This policy has evolved saltatorially over the 111 years since Yellowstone National Park was created. Early policies emphasized management of the scene that existed when Europeans first arrived. Present policy emphasizes management for unimpeded natural processes. Each stage in the evolution of society's attitudes toward forest land has altered and will continue to alter National Park Service fire policy.

Introduction

Changes in the management of fire in national forests have always been closely affiliated with changes in the perceived function of those forests. Timber production, grazing, recreation, promotion of wildlife, and wilderness preservation are goals that elicit different fire management programs. Given present-day knowledge of fire ecology and fire husbandry techniques, selecting the appropriate fire management program is a relatively straightforward process. For the U.S. Department of the Interior, National Park Service, the goals have never been so clear cut.

The Yellowstone Act of 1872 created a "public park or pleasuring ground for the benefit and enjoyment of the people" in which "the natural curiosities or wonders" were to be maintained "in their natural condition." In 1916, Congress created the National Park Service through the National Parks Act, and that legislation's visionary language directed the new agency "to conserve the scenery and the natural historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (fig. 1).

Figure 1—*The National Park Service was established for the protection of natural features and the pleasure of visitors. The role of fire in park management has evolved greatly since 1916.*

[1] Reprinted from the Proceedings of the Symposium and Workshop on Wilderness Fire, Missoula, MT, November 15-18, 1983.

Era of Spectacles

From 1886 to 1916, when the U.S. Army administered the national parks, and for the first 50 years of National Park Service management, the mandate from Congress was interpreted in a way that excluded fire management (*15*). In fact, the early national parks were selected for their scenery and spectacles—geysers, waterfalls, big trees, deep canyons. Protecting these phenomena and providing opportunities for enjoyment of the scenery was Park Service policy, taken directly from the 1916 law. The policy was interpreted to mean fire exclusion. That fire suppression in some areas creates its own long-term threat to safety and scenic resources was not yet appreciated.

During this initial period, the Park Service lacked the professional cadre and sense of shared values already well developed in the USDA Forest Service (*15*). In most cases it was the Forest Service that planned and conducted firefighting in the national parks. Park Service firefighting did not come into its own until the 1930's.

The management of national parks for protection of natural features and for the pleasure of visitors led to tourist accommodations directly abutting those natural features and the creation of new amusements such as bear-feeding stations and the famous Yosemite firefall. To protect living scenery, forest insects and diseases were fought with pesticides and prophylactic cutting without regard to whether the phenomena were natural, exotic, or aggravated by human presence (*9*). Management of wildlife was largely an ad hoc affair. Although traditional Park Service policy long has been "to permit each species of wildlife to carry on its struggle for existence without artificial help" (*9*), individual superintendents regularly ordered reductions of hoofed animals when they were believed to be overstocked or damaging vegetation.

Thanks to work by scientists such as Adolph Murie and George Wright, the policy of destroying predators to increase ungulates and reduce activities offensive to some visitors was gradually abandoned in the 1930's (*19*). By the end of the decade, authors of internal documents (*4*) and popular articles (*5*) were questioning the Park Service habit of feeding bears and then killing them when they became nuisances. But despite valuable advice from people within and outside the agency, the Park Service lacked a substantive resource policy. Furthermore, no professional scientists and resource managers were available to give life to such a policy.

Era of Resource Management

National park resource management entered a new age in 1963 when an advisory board on wildlife management appointed by then Secretary of the Interior Stewart Udall filed its report entitled "Wildlife Management in the National Parks" (*11*). The Leopold Committee far exceeded its formal directive and produced a document that spoke to the broad issue of goals and policies for natural resource management in the national parks. Its words were transformed into official policy:

> As a primary goal, we would recommend that the biotic associations within each park be maintained, or where necessary recreated, as nearly as possible in the condition that prevailed when the area was first visited by the white man. A national park should represent a vignette of primitive America.

With this goal clearly and formally stated, the committee said that means to achieve it could include reintroducing extirpated species, controlling or eliminating exotics, and managing population where natural controls or park size and necessary habitat components were inadequate. Although time and patience might restore climax communities disrupted by fire, logging, or other disturbances, the loss of serial and other fire-dependent communities could only be restored by reintroducing fire. For the Sierra Nevada of California, the report specifically recommended controlled burning as the only method that could extensively

The Park Service had two distinct reasons for introducing prescribed fire into its natural areas.

reduce "a dog-hair thicket of young pines, white fir, incense cedar, and mature brush—a direct function of overprotection from natural ground fires."

The Leopold Committee restated views enunciated in 1962 at the First World Conference on National Parks. There it had been suggested that park management served a homeostatic function, substituting artificial controls for natural ecologic factors that had been lost on account of inadequate park size, extirpation, or cumulative human activities. The Leopold Committee report stressed the management of a *scene* and defined that target scene explicitly as the moment when Europeans first laid eyes on it: "A reasonable illusion of primitive America could be recreated, using the utmost in skill, judgment, and ecologic sensitivity."

Possibly the most far-reaching recommendation of the Leopold Committee was to develop a professional cadre of scientists and resource management specialists within the National Park Service:

> Active management aimed at restoration of natural communities of plants and animals demands skills and knowledge not now in existence. A greatly expanded research program, oriented to management needs, must be developed within the National Park Service itself. Both research and the application of management methods should be in the hands of skilled park personnel.

The Leopold Committee report provided a long-delayed rationale for managing natural or wilderness areas in national parks. It called for acquiring scientific information so that the "vignette of primitive America" could be determined and the tools best able to restore it selected. It repeatedly specified controlled burning as a preferred tool for manipulating vegetation because of its low cost and its ability to simulate the effects of wildfire.

Those familiar with the writings of John Muir know that his descriptions of open stands of conifers on the western slopes of the Sierra Nevada and his reports of frequent fires set by local Indians (and at that time ranchers as well) conflicted sharply with conditions in Yosemite and Sequoia National Parks in the latter part of the 20th century. Reports by Hartesveldt and his coworkers (*6*, *7*) found a classic example of fire dependence in the giant sequoia (*Sequoiadendron giganteum*). The era of suppression apparently had drastically reduced reproduction while encouraging undergrowth that jeopardized the famous giants when fire did—inevitably—recur.

Biswell (*2*) provided the technical basis for fuel reduction by prescribed fire, and the National Park Service at last felt it had the policy imperative, the biological justification, and the technical skills to introduce this management technique. As Pyne (*15*) reports, early successes in the Sierra Nevada emboldened resource managers, and the 1970's were years of enthusiastic experiments with prescribed fires in several national parks. Unfortunately, in some of these experiments enthusiasm exceeded fire management techniques or a full understanding of the ecological consequences.

The Park Service had two distinct reasons for introducing prescribed fire into its natural areas. The first was that nearly a century of fire suppression presumably had altered pristine plant communities, and living and dead fuels constituted a threat of unnaturally hot and dangerous wildfire that imperiled park resources, people, and surrounding lands. These threats and their reduction through prescribed fire rapidly became incorporated into management documents (*17*, *18*).

Fires produced by natural ignition sources were permitted to burn with increasing frequency, but only insofar as they were within prescription and furthered management objectives. As natural areas were modified by prescribed fire, managers felt that reduced fuel loadings would permit larger proportions of the parks to be included in natural fire zones. Both natural and prescribed fires, however, were intended to serve the same end: restoring and perpetuating Leopold's vignette of "primitive America."

Evidence continues to accumulate that, throughout much of the world, aboriginal humans greatly influenced vegetation by burning (*15*). This appears to be true of California, including the Sierra Nevada (*12*). When Kilgore and Taylor (*10*) reconstructed the fire history of sequoia-mixed conifer forest, they found a fire frequency substantially greater than one that could be generated by contemporary natural ignition rates, and concluded that Indians were responsible for a large but undetermined proportion of the fire scars they found. Partly because it is now difficult to distinguish the historic effects of aboriginal burning from those of lightning-caused ignitions, and partly because the Leopold Committee report specifically referred to "the condition that prevailed when the area was first visited by the white man" (from which one may infer that Indians were to be included), managers in the Sierra Nevada parks have been inclined to merge both ignition sources and their ecologic effects when calculating "natural" vegetation patterns and developing prescribed burning plans. Similar Indian burning effects have been noted and similar management conclusions drawn for other areas, such as the northern Rocky Mountains (*1*).

Under the Leopold approach, resource managers in a growing number of western parks with significant natural or wilderness areas have made their first step to restore vegetation structure to what it was in presettlement times, generally defined as approximately a century ago. In most cases, that

Sequoia and Kings Canyon National Parks

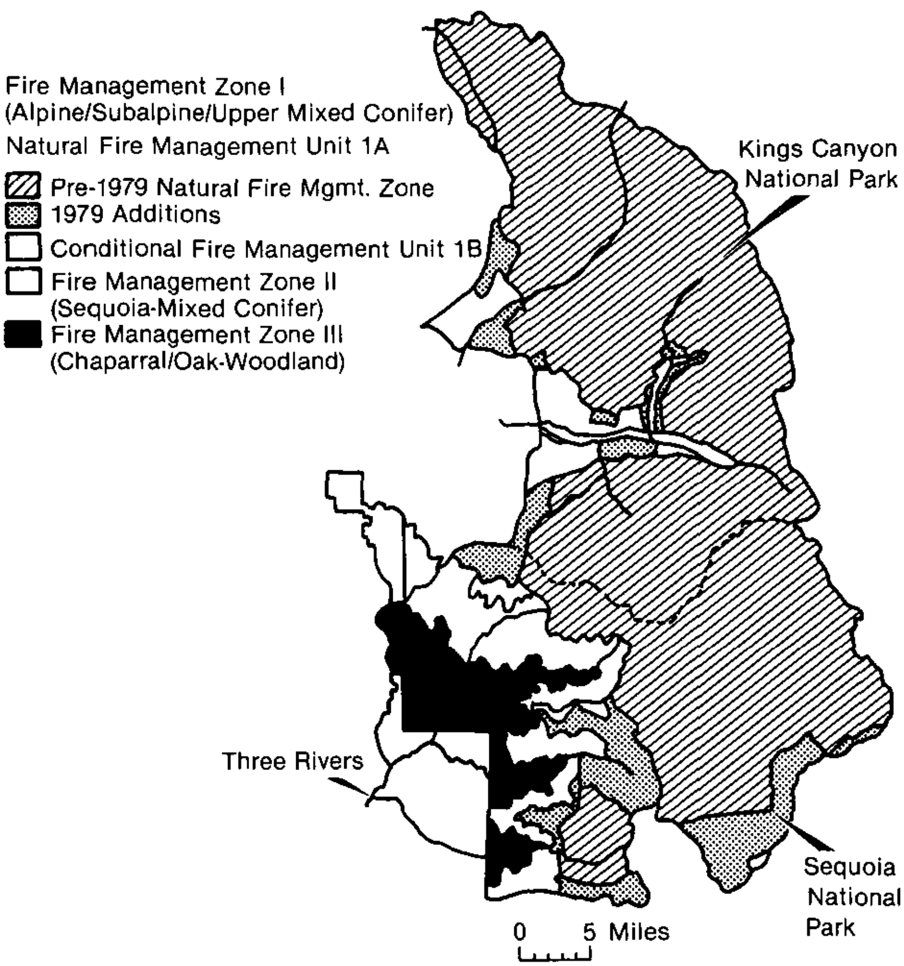

Figure 2—*Fire management zones for Sequoia and Kings Canyon National Parks.*

. . . parks are ecologic islands and cannot be managed as limitless wilderness.

structure has been estimated from present stand structure, fire scars and other physical evidence, historical records, and inferences drawn from similar vegetation elsewhere. All of these techniques—except in rare instances where actual reports of Indian burning frequency and extent are available—lump ignition sources for past fires. A combination of mechanical manipulation and prescribed fire has then been applied.

Although not always explicitly stated, program objectives for the "first round" of burning programs generally include (1) restoring the presettlement scene; (2) protecting visitors, structures, featured resources, and designated scenery; and (3) preventing, as an outcome of ignition from any source, uncontrolled wildfire that could burn areas within or outside park boundaries in an unacceptable fashion. The rationale for this approach is fully developed by Parsons (*14*).

As techniques for burning have developed to the point where first-round fire management programs can be implemented successfully, managers have been confronted with the dilemma of where to proceed next. In natural areas, one is left with the alternatives of ceasing prescribed burning and permitting natural ignitions to provide the sole source of fire, or of supplementing/supplanting natural ignitions indefinitely with prescribed fires whose parameters would be determined by available information on presettlement fire behavior, present and past vegetation structure, or both. In practice, the first alternative is unlikely ever to be implemented strictly. Protection of various resources and conflicting fire policies on adjoining lands will require prescribed fire for reasons other than ecological objectives. The second alternative is obligatory if Indian burning was a significant factor in creating the presettlement scene.

Era of Ecological Reserves

As many wild ecosystems are compromised by a variety of human activities, such as mining, grazing, logging, and recreation, those that are left untouched become increasingly valuable as living laboratories of natural ecological processes. Their value as controls in a world where human influence is virtually omnipresent varies inversely with the degree to which they disturbed. This newly emphasized function of natural area is explicitly recognized by the dedication of International Biosphere Reserves under UNESCO's Man and the Biosphere Program. American biosphere reserves include not only national parks but also land managed by other agencies, and include both natural and manipulated sites (*16*).

For the National Park Service, recognizing the scientific values of natural or wilderness areas introduces some conflicts with other approaches. Human visitation, which is already acknowledged to compromise wilderness value when it reaches certain levels, may significantly compromise information of scientific value by setting up scientific equipment, destructive sampling of resources, and other visual or acoustic blights on an otherwise unmarred landscape. For the National Park Service, these conflicts remain unresolved at the policy level.

The Leopold approach of scene management is incompatible with management for unimpeded natural processes. By designating a particular set of conditions as a "reasonable illusion of primitive America" and calling upon both natural and artificial processes to achieve it, new anthropogenic artifacts—however subtle or artful—are introduced into the system and compromise any study of natural processes. An alternative approach recognizes, as did the Leopold Committee, that parks are ecologic islands and cannot be managed as limitless wilderness. This approach still requires revising or mitigating anthropogenic effects in natural areas. But by abandoning the notice of an end product—the "correct" scene—natural processes are permitted to proceed unimpaired within previously stated constraints of protection of life, property, and designated resources. This new perspective recognizes that ecosystem processes and ecosystem elements are interdependent and that both are valid and important objects of study.

The natural process approach to wilderness management obviates some difficulties with the Leopold model and introduces a few of its own. Cycles and trends in climate, erosion, and plant succession are no longer considered management issues; they can be observed rather than confronted. Wildlife population phenomena such as epizootics, irruptions, and collapses are also no longer at issue. What once were problems are now phenomena. Simulation of aboriginal burning is inappropriate because it freezes a moment in Indian cultural evolution, climate, and biotic relations for all time. Had they been free to follow their own cultural destiny, Indians presumably would not have pursued deer, collected acorns, and ignited fires in perpetuity.

Bonnicksen and Stone (*3*) elucidate some of the inherent contradictions in what they call "structural maintenance objectives" and point out the interdependence of structure and process. They claim that in the Sierra Nevada sequoia-mixed conifer forest, changes in forest structure produced by decades of fire suppression have now sufficiently altered fire behavior so that fire/forest interactions with or without simulated Indian burning do not follow the pattern that would have prevailed had Europeans never entered the scene. Bonnicksen and Stone focus on relatively short-term phenomena and ignore long-term variations produced by climatic cycles that could far outweigh human influence.

A serious difficulty in permitting unimpeded natural processes in national park natural areas is that there is little information on the anthropogenic factors that need to be corrected. Without data on long-term lightning ignition and spread patterns, we cannot compensate for loss of fires that previously invaded from beyond park boundaries. When ungulate populations explode and collapse, is it from loss of predators or habitat beyond park boundaries or a natural phenomenon? That kind of information can be obtained only by scientific study. The study of wildfire pattern and process is itself valid, but repeated observation is needed. National Park wildernesses have fewer confounding variables than most other sites.

A greater difficulty in implementing a natural process approach may be that high-intensity, extensive conflagrations are frightening, dangerous, and unpopular. Evolving fire management techniques may eventually permit more frequent containment and less outright suppression of chaparral fires and forest crown fires, but until then lower intensity, partial simulations must suffice. In the many locations where fuel buildup from fire suppression would produce an unnaturally hot wildfire, prescribed fire remains the necessary first step.

The ecological reserve approach to national park wilderness and natural areas is compatible with the Wilderness Act of 1964 and the philosophy behind the act as developed by Nash (*13*). The role of fire in park wilderness is substantially that described by Heinselman (*8*). Although national parks have traditionally emphasized the recreational use of wilderness for its esthetic and spiritual value, that emphasis can be harmonious with preserving the parks as reserves of wild natural objects and processes from which we can learn more about the world and how we have changed it and continue to change it.

Literature Cited

1. Barrett, Stephen W.; Arno, S.F. Indian fires as an ecological influence in the Northern Rockies. Journal of Forestry. 80(10): 647–651; 1982.
2. Biswell, Harold H. Forest fire in perspective. Proceedings of the Tall Timbers Fire Ecology Conference. 7: 43–63; 1967.
3. Bonnicksen, Thomas M.; Stone, E.C. Managing vegetation within U.S. National Parks: a policy analysis. Environmental Management. 6(2): 101–102, 109–122; 1982.
4. Dixon, Joseph S. Special report on bear situation at Giant Forest, Sequoia National Park, California. Washington,

DC: U.S. Department of the Interior, National Park Service; 1940. 5 p.
5. Finley, William L.; Finley, I. To feed or not to feed . . . that is the bear question. American Forestry. 46(3): 344-347, 368, 383-384; 1940.
6. Hartesveldt, Richard J.; Harvey, H.T. The fire ecology of sequoia regeneration. Proc. Tall Timbers Fire Ecol. Conf. 7: 65-77; 1967.
7. Hartesveldt, Richard J.; Harvey, H.T.; Shellhammer, H.S.; Stecker, R.E. The giant sequoia of the Sierra Nevada. Publ. No. 120. Washington, DC: U.S. Department of the Interior, National Park Service; 1975. 180 p.
8. Heinselman, Miron L. Fire in wilderness ecosystems. In: Hendee, John C.; Stankey, George H.; Lucas, Robert C., eds. Wilderness management. Misc. Publ. 1365. Washington, DC: U.S. Department of Agriculture; 1978: 249-278.
9. Ise, John. Our national park policy. Baltimore, MD: Johns Hopkins Press; 1961. 701 p.
10. Kilgore, Bruce M.; Taylor, D. Fire history of a sequoia-mixed conifer forest. Ecology. 60: 129-142; 1979.
11. Leopold, Aldo S.; Cain, S.A.; Cottam, D.M.; Gabrielson, I.M.; Kimball, T.L. Wildlife management in the national parks. Trans. North Am. Wildl. Nat. Res. Conf. 28: 28-45; 1963.
12. Lewis, Harry T. Patterns of Indian burning in California; ecology and ethnohistory. Ramona, CA: Ballena Press; 1973. 101 p.
13. Nash, Roderic. Historical roots of wilderness management. In: Hendee, John C.; Stankey, George H.; Lucas, Robert C., eds. Wilderness management. Misc. Publ. 1365. Washington, DC: U.S. Department of Agriculture; 1978; 27-40.
14. Parsons, David J. The role of fire management in maintaining natural ecosystems. In: Mooney, H.A.; Bonnicksen, T.M.; Christensen, N.C.; Lotan, J.E.; Reiners, W.E., eds. Fire regimes and ecosystem properties: Proceedings; 1978 December 11-15; Honolulu, HI. Gen. Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981: 469-488.
15. Pyne, Stephen J. Fire in America: a cultural history of wildland and rural fire. Princeton, NJ: Princeton University Press; 1982. 654 p.
16. Risser, Paul G.; Cornelison, Kathy D. Man and the biosphere. Norman, OK: University of Oklahoma Press; 1979. 109 p.
17. U.S. Department of the Interior, National Park Service. Fire management plan. Three Rivers, CA: U.S. Department of the Interior, National Park Service, Sequoia and Kings Canyon National Parks; 1979. 171 p.
18. Van Wagtendonk, Jan W. Refined burning prescriptions for Yosemite National Park. Occas. Paper No. 2. Washington, DC: U.S. Department of the Interior, National Park Service; 1974. 21 p.
19. Wright, George M.; Dixon, J.S.; Thompson, B.H. A preliminary survey of faunal relations in national parks. Fauna Ser. No. 1. Washington, DC: U.S. Department of the Interior, National Park Service; 1933. 157 p. ■

New Tools

The National Volunteer Fire Council (NVFC) is offering a kit of public relations and fire prevention materials free of charge to any fire department. The kit, called "New Tools for Volunteer Fire Fighters," includes advertisements to help departments recruit, raise funds, and promote fire safety through their local newspapers and magazines, as well as a tape of radio announcements recorded by race car driver Richard Petty. A television public service announcement on recruiting is also available through the NVFC directors. For more information, contact:

Gus Welter, NVFC Secretary
9944 Harriett Avenue
Bloomington, MN 55420 ■

A Method To Assess Potential Fire Season Severity

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Abstract: Long-term monthly precipitation data were used to estimate the chance for a severe fire year. Monthly precipitation values were compared with past severe fire seasons to estimate the future occurrence of severe fire seasons. Fire season severity was successfully predicted for fire seasons of 1983, 1984, and 1985 using this approach on the Okanogan National Forest.

Introduction

A method to systematically evaluate the probability of fire season severity prior to the central part of the fire season would assist managers in preplanning deployment of people and equipment. Tentative assignment of fire personnel and equipment can be made to maximize fire prevention and protect resources. Placing people and equipment for the most effective use and benefit is important.

Different fire control strategies are used in different areas of a forest. These control strategies may vary throughout the fire season. The fire season severity evaluation is an important part of the decision tree that determines the action to be taken in confinement and containment fire strategy areas.

Background

Probability concepts are used in many hydrological and engineering projects. One of the basic designs used is the frequency series, the listing of a range of values in order of magnitude (Lindsey and Franzini 1964).

Fire management staff on the Okanogan National Forest have estimated potential fire season severity from precipitation values for certain locations. When precipitation over a given period of time was low, a severe fire season was assumed to be ahead. High precipitation indicated a low likelihood of fires.

Fire management needed a more systematic approach to be able to better define the levels of "low" precipitation and what the probability of a severe fire season was, by means of readily available precipitation values.

Components of the Method

Monthly Precipitation—Low monthly precipitation totals do indicate higher probability of a severe fire season. Monthly precipitation values or combinations of monthly precipitation values were totaled for each year for each station. This can be any combination of months which contribute to fire season severity. Totals for each year of record were listed in order from the lowest to the highest in a frequency series. Four stations were tested for the general forest zone, Nespelem, Conconully, Winthrop, and Mazama. Information on precipitation values is found in "Climatological Data" for Washington State, published in annual summaries by the National Oceanic and Atmospheric Administration.

Severe Fire Seasons—The frequency series of monthly precipitation is compared to severe fire season occurrence.

Deciding what constitutes "severe" fire seasons is important to objectively determine the probability of severe fire season occurrence by precipitation totals. There are several methods for determining or indexing fire season severity, but no common agreement on any method currently exists. Some sources for determining severe fire seasons include: (1) records of large acreages burned, (2) drought records that indicated severe fire potential or occurrence, (3) personal experience and/or knowledge of someone else's personal experience, (4) fire atlas records, (5) vegetation growth records (tree ring surveys), and (6) fire season severity index of one's choice. The first four of these criteria were used to identify the severe fire years for the Okanogan National Forest.

Severe fire years used for the general forest zone on the Okanogan National Forest were 1910, 1919, 1926, 1928, 1929, 1930, 1934, 1938, 1939, 1944, 1945, 1961, 1962, 1967, 1970, 1973, 1977, and 1979. Severe fire years for the high elevation lands were 1910, 1928, 1929, 1930, 1967, and 1970.

Correlation

Table 1 shows a comparison between precipitation values and severe fire years. Severe fire seasons tend to correlate with the lowest precipitation, although some factors may have kept the lowest precipitation years from being severe. For example, temperatures may have been below normal or wind movement was below normal.

The correlation of severe fire seasons to total precipitation values is expressed as percentage (column 6, table 1). The percentage is the probability of occurrence for a severe fire season with a given precipitation range.

Using the percent probability as a management tool requires estimating values that have the greatest spread. *In this example, maximum* probability is 60 percent (5 years). Whenever the current precipitation, in this example, was 1.27 inches or less, there was a 60-percent chance of a severe fire year. In the future this means if there is less than 1.27 inches of precipitation there is a 60-percent chance of a severe fire season occurrence.

The next step is to calculate probability of severe fire seasons for other precipitation totals. All rows of table 1 with precipitation less than or equal to 1.27 are not considered any further. The ranges of precipitation are determined subjectively and depend on precipitation totals or other factors important to the user. The cut off used in table 2 is 3.00 inches of precipitation. Table 3 includes years with 3.01 to 5.00 inches of precipitation. Table 4 lists the cor*relation between severe fire seasons* and more than 5.01 inches of precipitation.

The probability of a critical fire season developing is shown in table 5 for given precipitation ranges. This table can be used in risk assessment.

The result is a probability table of a severe fire season occurring which is based on past occurrence (table 5).

Table 1—*Comparison of precipitation (less than 1.28 inches) with severe fire season years*

(1) Total years	(2) Precip year	(3) Frequency series of total precip. for selected period (in)	(4) Severe fire year correlation	(5) Severe fire year correlations vs. total years	(6) Percent probability
1	1937	.75	No	0/1	0
2	1973	.95	Yes	1/2	50
3	1960	1.20	No	1/3	33
4	1979	1.25	Yes	2/4	50
5	1967	1.27	Yes	3/5	60
6	1975	1.39	No	3/6	50
7	1961	1.50	Yes	4/7	57
8	1957	1.79	No	4/8	50
9	1970	1.82	Yes	5/9	56
10	1964	1.83	No	5/10	50

Table 2—*Comparison of precipitation (1.28—3.00 inches) with severe fire season years*

Total years	Precip year	Frequency series total precip for selected period (in)	Severe fire year correlation	Severe fire year correlations vs. total years	Percent probability
1	1975	1.39	No		
2	1961	1.50	Yes	(1)	
3	1957	1.79	No		
4	1970	1.82	Yes	(2)	
5	1964	1.83	No		
6	1963	1.87	No		
7	1929	2.01	Yes	(3)	
8	1930	2.07	Yes	(4)	
9	1980	2.21	No		
10	1934	2.31	Yes	(5)	
11	1954	2.47	No		
12	1955	2.79	No		
13	1974	2.91	No		
14	1981	2.98	No	5/14	36

Table 3—*Comparison of precipitation (3.01—5.00 inches) with severe fire season years*

Total years	Precip year	Frequency series total precip for selected period (in)	Severe fire year correlation	Severe fire year correlations vs. total years	Percent probability
1	1978	3.07	No		
2	1953	3.21	No		
3	1959	3.21	Yes	(1)	
4	1935	3.27	No		
5	1945	3.47	Yes	(2)	
6	1971	3.59	No		
7	1956	3.78	No		
8	1949	3.81	No		
9	1969	3.94	No		
10	1951	4.12	Yes	(3)	
11	1950	4.37	No		
12	1972	4.94	No	3/12	25

Table 4—*Comparison of precipitation (more than 5.01 inches) with severe fire season years*

Total years	Precip year	Frequency series total precip for selected period (in)	Severe fire year correlation	Severe fire year correlations vs. total years	Percent probability
1	1968	5.01	Yes	(1)	
2	1947	5.27	No		
3	1965	5.31	No		
4	1943	5.47	No		
5	1969	5.61	No		
6	1931	5.69	No		
7	1966	5.98	No		
8	1932	6.47	No		
9	1948	7.32	No		
10	1946	7.33	No	1/10	10

Table 5—*Probability of severe fire occurrence based on monthly precipitation*

Precipitation (inches)	Probability of severe fire season (percent)
Less than 1.27	60
1.28–3.00	36
3.01–5.00	25
More than 5.01	10

Analysis

Combination of monthly precipitation totals for stations on or near the Okanogan National Forest were compared against the critical fire seasons. The Nespelem station provided the closest correlations between severe fire seasons and precipitation on the Okanogan National Forest.

Different combinations of months allow tracking of precipitation totals through the beginning of the fire season so that several combinations of monthly precipitation can be analyzed (table 6).

Table 6—*Probability of severe fire occurrence based on monthly precipitation*

Monthly combination	Precipitation total (inches)	Probability of severe fire year season (%)
March–April	Less than .65	80
	Less than.80	71
	.65–1.93	30
	Greater than 1.94	12
March–April–May	Less than 1.05	60
	1.06–2.60	36
	Greater than 2.60	14
March–April–May–June	Less than 1.09	100
	1.10–1.30	75
	1.31–2.45	33
	Greater than 2.46	22
March–April–May–June–July	Less than 1.75	75
	1.75–2.80	50
	2.81–4.28	29
	Greater than 4.28	10

This approach uses monthly precipitation values because these values are available for many years. However, the use of monthly precipitation may be misleading. Some of the events creating a severe fire season are short term and may not be reflected in monthly precipitation values. For example, monthly precipitation values for May and June may be high. These values do not show, however, when the precipitation occurred. If the average precipitation for May and June fell the first few days of May and then was dry until the last few days of June, heavy fuels may have dried out sufficiently to create severe fire conditions, and the late June rain may cause only a temporary wetting of the fine fuels, which could dry out quickly. Severe fire situations could exist even though precipitation levels were near or above average. There are factors not reflected in monthly precipitation values that influence fire severity; for example, high velocity winds, low humidity, and high incidence of solar radiation. Heavy precipitation overcomes other contributing factors of severe fire seasons. The probability is substantially lower after some level of precipitation.

Precipitation values for February and March on the Okanogan National Forest usually provide little predictive capability. Precipitation falls on snow or wet heavy fuels, not substantially changing fuel conditions.

June and July precipitation increases the probability estimate because precipitation in these months influences fuel moisture during the probable burning period. Precipitation values of April and May should be considered as contributing some predictive capability and early-on assistance in fire planning.

Different monthly combinations of precipitation were considered, some being more suitable than others. The months of August and September were eliminated because when monthly precipitation values were available, the peak fire season was normally already well established.

Summary

According to table 1, when precipitation was below 1.25 inches, severe fire years occurred 60 percent of the time. The severe fire years may occur in succession or be separated by several years, but over the long term, 60 percent of the fire years will be severe if the precipitation is less than 1.25 inches.

The method described has been used on the Okanogan National Forest the past three fire seasons. In each of the past 3 years the fire season severity was correctly projected. The precipitation totals for 1985 were used this year to help make midseason adjustments in confinement and containment fire strategies. Precipitation levels from the analysis of past years were put into the decision criteria to help determine when confinement fire strategies would become containment or control strategies.

This method allows fire managers to systematically establish the probability of a severe fire season based on past fire severity and precipitation values. This information can help determine needs for prevention and suppression before the hot part of the fire season. The information is also used to determine control status of current or future fire control strategy.

Literature Cited

Linsley, Ray K.; Franzini, Joseph B. Water resources engineering. New York: McGraw-Hill; 1964 (p. 110-132).■

Intermountain Research

The Intermountain Forest and Range Experiment Station, headquartered in Ogden, UT, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the station territory is classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries, minerals for energy and industrial development, and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Field programs and research work units of the station are maintained in:

- Boise, ID
- Bozeman, MT (in cooperation with Montana State University)
- Logan, UT (in cooperation with Utah State University)
- Missoula, MT (in cooperation with the University of Montana)
- Moscow, ID (in cooperation with the Univeristy of Idaho)
- Provo, UT (in cooperation with Brigham Young University)
- Reno, NV (in cooperation with the University of Nevada) ■

The USDA Forest Service Wildfire Program

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For 80 years, the USDA Forest Service has been the leader in the United States, and in most of the world, in forest fire management. Three branches of the Forest Service are involved with forest fire management activities.

The National Forest System, by far the largest of the three branches, is responsible for fire protection on almost 200 million acres of national forests and grasslands and on some adjacent and intermingled lands—an area that is about twice the size of the State of California.

State and Private Forestry (Cooperative Fire Protection) cooperates with State forestry agencies and private landowners engaged in forest fire activities.

Research staff members develop and extend knowledge about fire prevention and management. Such knowledge has helped solve many of the critical fire problems that have faced foresters for the past half a century.

To control or manage fires on National Forest System lands, the Forest Service has built one of the world's largest fire protection organizations, a group comprising between 10,000 and 20,000 men and women, depending on the time of year and the severity of the fire season (fig. 1). This organization engages in fire prevention, fuel modification, fire detection, presuppression activities, and fire suppression.

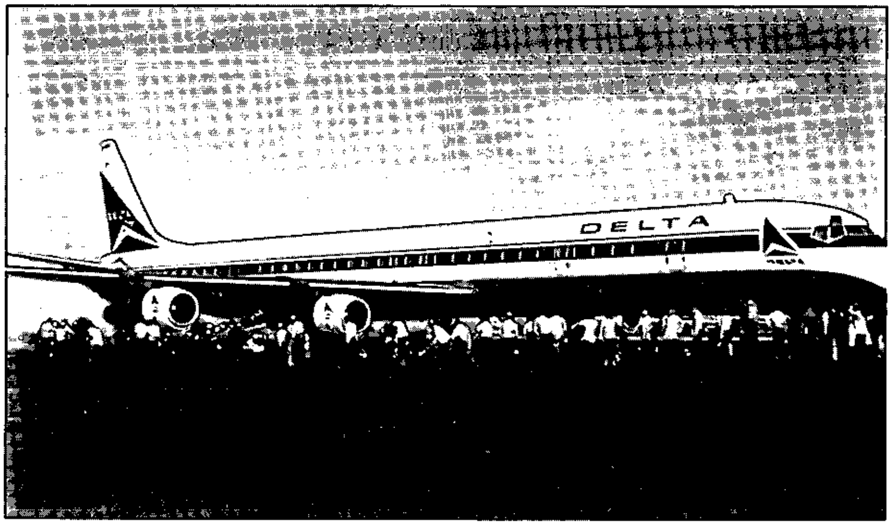

Figure 1—*Forest Service interregional fire crew.*

Before 1972, fire management was called fire control, and the primary mission was to prevent or control all forest fires. In 1971, the Forest Service decided that merely reacting to fires that had already started was not adequate and a broader approach was needed. The concept of greater preparedness involving increased presuppression activities began to receive new emphasis. More recently, the Forest Service further expanded fire management to include the reintroduction of fire to its natural role in selected forest ecosystems.

To achieve its goals, the Forest Service uses prescribed fire, either by starting a fire or allowing a wildfire to continue to burn under a carefully predetermined set of weather, topographic, and fuel conditions (fig. 2). The objectives of prescribed fire can be as varied as the forests of this Nation, ranging from reducing the flammability of chaparral in southern California to disposing of logging debris in the Pacific Northwest to killing fungus pests in the Southeast.

The Role of the States

Perhaps as important as the fire management program on national forest land has been the ever increasing amount of non-Federal land brought under fire protection.

The Cooperative Forest Fire Control Program started under a provision of the Weeks Act of 1911. The law authorized the Secretary of Agriculture to enter into agreements with the States "to cooperate in financing the organization and maintenance of a system of fire protection on any

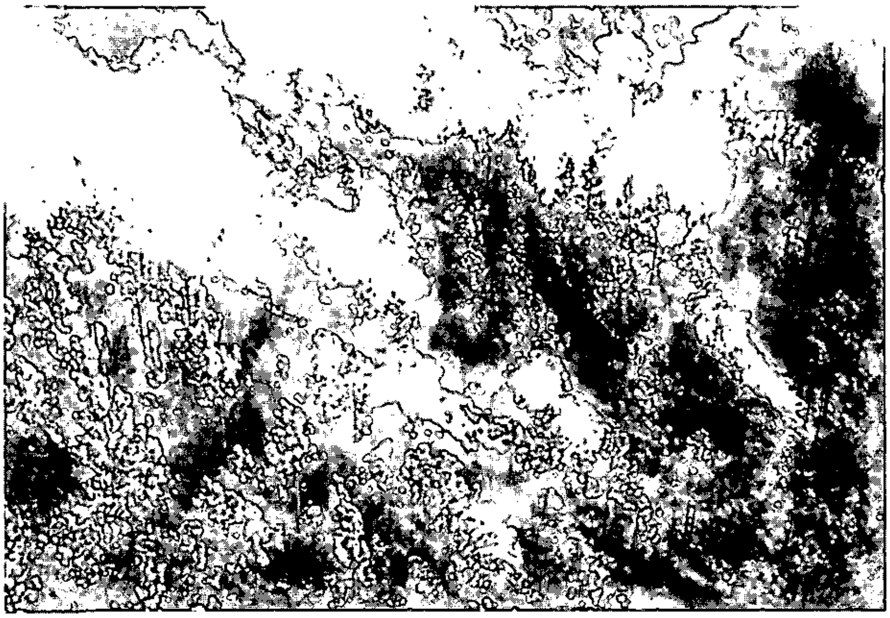

Figure 2—*Prescribed burning is one of the fire management techniques currently being used by the Forest Service.*

private or State forest lands on the watershed of a navigable river." Under the law, cooperating States had to provide for a system of fire protection to which the Federal Government could contribute as much as one-half the cost.

The Clarke-McNary Act of 1924 broadened and strengthened the provisions of the Weeks Act. Section 2 of the Clarke-McNary Act authorized extension of the Cooperative Forest Fire Control Program to include all forest and critical watershed lands in State and private ownerships.

These two laws prepared the way for steady progress in fire protection for the Nation's forested and nonforested watershed lands. In 1917, only 21 States were cooperating under the Weeks Act; by 1966, all 50 States were cooperating under the Clarke-McNary Act.

The Cooperative Forestry Assistance Act of 1978 superseded the Clarke-McNary Act. This new act speaks directly to recent program activities that have emerged as part of the cooperative program with the States, and it authorized the development of systems and methods for improving program effectiveness.

The Cooperative Forestry Assistance Act recognized that fire protection on State and private lands is a State responsibility. The newly defined Federal role is to promote more efficient State protection by targeting Federal funds.

These aggressive programs, both Federal and State, have been expensive. According to a conservative estimate, the cost of fire protection for all wildland agencies rose from about $100 million annually in 1965 to more than $600 million by 1983. Forest firefighting emergency funds, which tripled between 1965 and 1983, made up a significant part of these costs.

Although the program has been expensive, it has also been effective. The number of fires per million acres protected has declined from more than 250 in 1917 to about 100 in 1983. The reduction in acres burned is even more dramatic, from 20,000 per million acres protected in 1917 to slightly more than 1,100 in 1983.

But these numbers represent only part of the success story. Although the area under protection increased eightfold between 1917 and 1983, the total risk of fires starting, as measured by various types of land use, increased more than tenfold. Considering the increase in both the area protected and the risk of fire, agencies could have expected more than 350,000 fires in 1983. As a result of fire prevention efforts, however, only about 100,000 actually occurred.

Fire suppression efforts have also been successful. The fires that do start are controlled at a smaller size. Statistics show that losses from fire on protected areas might have exceeded 2.5 billion cubic feet of timber in 1981. However, with a reduction both in the number of fires and the average fire size, the loss of timber was less than 0.4 billion cubic feet and has continued to decline.

Because of the success in prevention and fire management, timber mortality by fire, on all protected areas, has been superseded as the chief cause of loss of both sawtimber and growing stock. Fire has fallen behind disease, insects, and weather as a major cause of timber loss.

The Role of Research

At the beginning of the 20th century, foresters were responsible for managing wild and remote areas in which the cause, behavior, and effects of fire were poorly understood at best. Early fire research was essentially management science—trying to determine the what, the how much, and the where of a fledgling fire control organization and then attempting to develop a policy for its use. Fire researchers and forest managers frequently traded roles.

Since World War II, however, the scope of fire research has expanded to include the physical, biological, and social sciences. Fire research today draws heavily on the fields of meteorology, engineering, public administration, and operations research. In the 1960's the emphasis was on suppression effectiveness, with advances made in air attack and retardant development. In the 1970's, weather research, fuels, fire effects, and prescribed burning were at the forefront. The knowledge, tools, methods, and strategies that fire managers use nearly every day have evolved to a large extent from fire research (fig. 3).

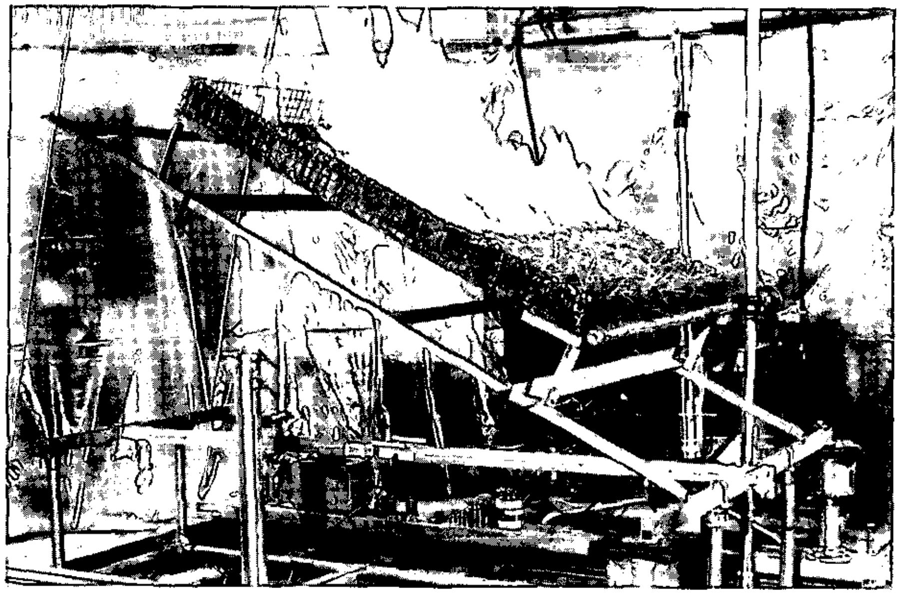

Figure 3—*One of many fire research tests conducted by the Forest Service.*

Despite such success, the statement "nothing succeeds like success" may not be true with respect to fire research. Whether fire research can continue to supply knowledge on a timely basis is uncertain; the budget for fire research has declined steadily since 1981. Furthermore, this reduction has occurred during a time when the cost of doing comprehensive research increased substantially.

Perhaps even more important, forest fire research as a percentage of the total Forest Service research budget and as a percentage of the Aviation and Fire Management suppression budget has declined substantially since 1974. This means that fire researchers are now less able to respond to user needs than they were a decade ago. Success in future years will depend on research managers making very wise decisions about research priorities. ■

Recent Fire Publications

Albini, Frank A. Wildland fires. American Scientist. 72: 590–597; 1984.

Barnes, Will C. Trailing a firebug. American Forests. 91(8): 17, 52–55; 1985.

Brown, J.K.; Marsden, M.A.; Ryan, K.C.; Reinhardt, E.D. Predicting duff and woody fuel consumed by prescribed fire in the northern Rocky Mountains. FSRP/INT–337. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 29 p.

Brown, Barbara G.; Murphy, Allan H. Quantification of uncertainty in operational and experimental fire-danger forecasts. Corvallis, OR: Oregon State University, Department of Atmospheric Sciences; 1984. 28 p.

Brown, Barbara G.; Murphy, Allan H. Verification of experimental probabilistic spot fire-weather forecasts. Corvallis, OR: Oregon State University, Department of Atmospheric Sciences; 1984. 44 p.

Dieterich, John H.; Swetnam, Thomas W. Dendrochronology of a fire-scarred ponderosa pine. Forest Science. 20(1): 87–96; 1985.

Donoghue, Linda R; Main, William A. Some factors influencing wildfire occurrence and measurement of fire prevention effectiveness. Journal of Environmental Management. 30(1): 238-247; 1984.

Furman, R. William. Evaluating the adequacy of a fire-danger rating network. Forest Science. 30(4): 1045–1058.

Gabriel, Herman W.; Talbot, Stephen S. Glossary of landscape and vegetation ecology for Alaska. Tech. Rep. 10. Anchorage, AK: U.S. Department of the Interior, Bureau of Land Management, Alaska State Office; 1984. 137 p.

Gharabegian, A; Cosgrove, K.M.; Pehrson, J.R.; Trinh, T.D. Noise exposure quantification analysis for forest fire fighters. Irvine, CA: Fluor Engineers, Inc., Environmental Services Dept.; 1984. 202 p.

Gonzalez-Caban A.; McKetta, C.W.; Mills, T.J. Cost of fire suppression forces based on cost-aggregation approach. Res. Pap. PSW–171. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1984. 22 p.

Huck, Chris. Burning the wilderness. American Forests. 91(8): 13–16, 55; 1985.

Murphy, Allan H.; Brown, Barbara G. The state of the art of probabilistic weather forecasting. Corvallis, OR: Oregon State University, Department of Atmospheric Sciences; 1984. 36 p.

National Wildfire Coordinating Group. Airtanker base planning guide. NWCG Pub. No. 440–1; NFES Pub. No. 1259. Boise, ID: Boise Interagency Fire Center, National Wildfire Coordinating Group; 1984. 29 p.

Nicholas, N.S.; White, P.S. Effect of the southern pine beetle on fuel loading in yellow pine forests of Great Smoky Mountains National Park. NPS/R/RM/SER–73. Gatlinburg, TN: USDI National Park Service, Uplands Field Research Lab; 1984. 40 p.

Radloff, D.L.; Freeman, D.R.; Yancik, R.F. FUELBEDEAST: User's guide for modeling activity fuels and fire behavior in eastern forests. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1984. 20 p.

Shute, Nancy. National Air and Space Museum has a jump on forest fires for its new exhibit. Smithsonian. 15(12): 167–170; 1985. ■

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