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Fuels and Fire in Land-Management Planning: Part 3. Costs and Losses for Management Options

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Contents

Abstract

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An approach is illustrated for computing expected costs of fire protection; fuel treatment; fire suppression; damage values; and percent of area lost to wildfire for a management or rotation cycle. Input is derived from Part 1, a method for collecting and classifying the total fuel complex, and Part 2, a method for appraising and rating probable fire behavior. This approach can be used locally for fire management and in land-management planning.

Keywords: Fire management, fuels (forest fire), fire behavior (forest), fire planning, management planning (forest).

Introduction

Land-management planning includes study of various use patterns and management intensities and alternatives. Evaluation of alternatives should address anticipated buildup of fuels that creates a wildfire hazard. Planning decisions affect potential for fire, which can either enhance or hinder achievement of management-planning goals. Land managers must consider both effects of fire and of alternative fire strategies (Egging and others 1980).

To judge among alternatives, planners need to know:

- What is the expected cost of fire protection?
- What is the expected cost of fuel treatment?
- What is the expected cost of wildfire suppression?
- What is the value of resource damage?

To supply reasonable answers, fire specialists need to know:

- Classification of fuel complexes in the planning area.
- Cost of fire protection associated with each fuel complex.
- Cost of fuel treatments associated with current management practices.
- Cost of suppression and value of damage for current wildfire losses.
- Number of acres usually damaged by wildfire under the existing fuel pattern.

The Pacific Northwest Forest and Range Experiment Station, in cooperation with the Pacific Northwest Region of the USDA Forest Service and the Siskiyou National Forest, initiated the Cal-Ore Pilot Test to develop techniques and procedures for meeting these needs. The study was on about 35,000 acres of the Illinois Valley Ranger District, Siskiyou National Forest, Oregon.

This is the final report of a three-part series. Part 1 (Maxwell and Ward 1981) describes a practical way to classify the total fuel complex. The objective for developing a fuel-classification system was to collect onsite fuel information from total drainage areas. To derive adequate answers for evaluating and projecting fire-behavior ratings and calculating costs and losses from wildfire, we recognized the need to describe all fuel components and link fuel type to land and vegetative types.

Part 2 (Maxwell and Sandberg, in review) describes a systematic means of using the fuel classification in Part 1 to appraise and rate probable fire behavior for local fuel conditions and construct fuel profiles and a fire-behavior map.

In Part 3, we show how the fire-behavior map and fire-behavior projections are used to produce:

- Costs of fire protection.
- Costs of fuel treatment.
- Costs of fire suppression and damage values.
- Percent of area lost to wildfire per management or rotation cycle.

Details are provided in this report on the steps accomplished in the pilot test:

- Summary of current fire-behavior potential.
- Summary and analysis of causes, extent, resource damage, and suppression costs of local wildfires.
- Development of a table of protection costs.
- Development of a table of fuel-treatment costs.
- Land-management plans and cost tables.

Also included are examples of:

- Management options.
- Projections of fire-behavior ratings.
- Projected costs of protection and fuel treatment.
- Projections of costs and losses from wildfire.
- Assembly of cost-loss projections.

This approach to computing the expected fire-management costs for various land-management alternatives differs from others that have been published in that site-specific fuel descriptions and fire-behavior estimates are used rather than stylized fuel models. It allows comparison of the costs of wildfire suppression with damage caused by alternative fuel treatments, but does not allow comparison of costs of changing fire-protection levels or suppression strategies.

Summary of Current Fire-Behavior Potential

The fire-behavior map (fig. 1) developed from appraisal of local fuel beds in Part 2 was used to determine the percentage of the total area falling in each fire-behavior class by making a map dot grid count:

Fire-behavior class	Percent area in class
	Percent
1	17
2	66
3	13
4	4

Seventeen percent of the area fell in fire-behavior classes 3 and **4,** the crucial classes where more than initial attack or local forces are needed to control a wildfire and damage goes beyond "acceptable" losses and costs.

Resource Damage and Suppression Costs of Local Wildfires

Statistics on acres burned and value of resource damage in the pilot-test area (part of Regional Planning Area V, which consists of the Rogue River, Siskiyou, and Umpqua National Forests) were derived using the Region 6 Fire History Program at the Fort Collins Computer Center for 1970 through 1979 (table **1**). We believe these figures represent acres burned in the test area. The method can be used for any management unit, for example, USDA Forest Service Region, National Forest, or Ranger District.

Lightning-caused fires burned 0.00176 percent of the planning area annually; fires caused by industrial use burned 0.00931 percent and by general public use, 0.00581 percent. The average damage value from these fires was $189 per acre (table 1). Cost of suppressing wildfire for the study area during the same period was $2.197,567 to contain fires to 4,587 acres—about $479 per acre.

Table 1—Region 6, area V (southwest Oregon) fire-statistics summary—acres burned1/ and dollar value of damage, 1970-79

	Causes of fires				
	Lightniny	Industrial	Public use	Total	Damage value
	Acres				Dollars
Total area burned	479	2523	1579	4587	868,000
					$\bar{X}$=189.27
Percent of total area protected	0.0175	0.0931	0.0581		
Percent of area burned per year	0.00776	0.00931	0.00581		

1/Total acres protected = 2,717,490.

Trends in historical data are used to project future prices and costs. Fundamental shifts in the forces of supply and demand as well as random events have affected historical data. Projections about the immediate future may be based on trends from the immediate past.

Unfortunately, data from the decade of the 1970's were affected by inflation (changes in the value of the dollar). Inflation is difficult or impossible to project from past trends. Therefore, data that are not corrected for inflation can seriously distort an economic analysis. For example, an item that cost $1.00 in 1979 cost about $0.50 in 1970. If the effect of inflation between 1970 and 1979 were removed, the real cost of the item would have been the same in both years. The analyst might assume that the real cost of what is purchased remains unchanged in the immediate future.

For short-range planning, land managers would like to know if costs in real (not inflated) dollars are increasing or decreasing and by how much. A two-step procedure can be used to project damage values and suppression costs. The first step is to remove effects of inflation from the historical data. To do this, actual damage and suppression costs from each year are multiplied by the appropriate adjustment factor shown in the third column of the following listing of Producer Price Index figures. The base year of our analysis is 1979. The third column is computed by dividing the Producer Price Index for 1979 by the index for each year. The Gross National Product Deflator could be used in place of the Producer Price Index.

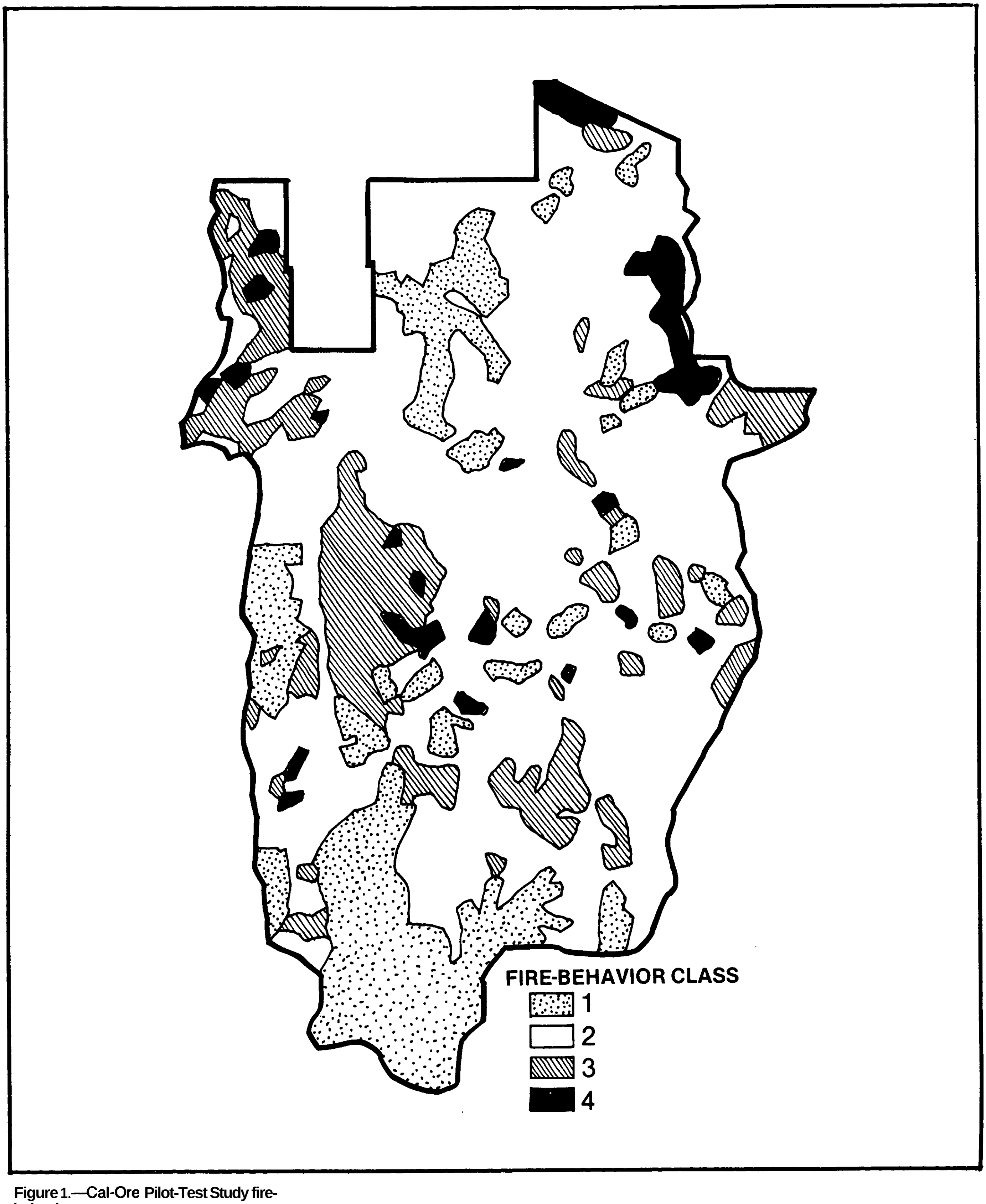

Figure 1.—Cal-Ore Pilot-Test Study fire-behavior map.

Year	Producer price index	Adjusted to 1979
1970	110.4	2.1313
1971	113.9	2.0658
1972	119.1	1.9757
1973	134.7	1.7468
1974	160.1	1.4697
1975	174.9	1.3453
1976	183.0	1.2858
1977	194.2	1.2116
1978	209.3	1.1'242
1979	235.3	1.0000

Adjusted to **1979** dollars, cost of damage was **$340** and suppression was **$740** in real dollars.

The average increase was **13** percent per year. If this trend continued through **1980,** the cost of doing the job then would be about **$836** per acre. Managers must project costs carefully, however, because trends can change from year to year.

The second step is to identify trends in real values and costs. One way is to ask the question: Was a trend in real suppression costs and real damage values detectable over the period **1970** to **1979?** To answer this question, we tested the hypothesis that costs and values, stated in **1979** dollars, were unchanged over time. The test was performed by regressing historical cost on time and then checking for a coefficient on the time variable that was significantly different from zero at the 0.05 level of significance. The following linear regression was used:

$$(\text{corrected cost}), = b_0 + b_1\ (\text{year})$$

where

(corrected cost), = cost in year t in **1979** dollars

(year) = **1970** through **1979**

b_0 = estimated intercept

b_1 = estimated trend coefficient on the time variable.

We tested the significance of b_1 using the Student's t-test. For suppression costs, the computed t-value was **1.53.** The critical t-value for the 0.05 level of significance was **2.262.** Because the computed value was less than the critical value, we concluded the evidence is insufficient to reject the hypothesis that b_1 is significantly different from zero. No linear trend occurred in real suppression costs between **1970** and **1979;** the damage values and suppression costs were the same throughout the study period. Analysis for damage values showed they, too, remained the same.

Projections of future suppression costs and damage values would be based on the assumption that past trends would continue. The analysis shows we would be justified in using the damage value of **$340** per acre and the suppression cost of **$740** per acre for projecting future damage values and suppression costs.

The economic consequences of fire-management activities can be measured by comparing benefits (damages that are avoided or revenues) and costs. A comparison can be made only if costs and benefits in the future are discounted to the same time. Typically, future real costs (in dollars corrected for inflation) and benefits are discounted to the present. Failure to discount costs and revenues correctly will seriously distort an economic analysis.

The present value of a sequence of suppression costs that will be incurred over the next **R** years can be written as:

$$PV_{cost} = C_1/(1+i)^1 + C_2/(1+i)^2 + \ldots + C_R/(1+i)^R \qquad (1)$$

where

PV = the sum of future real costs discounted to the present
C = annual cost
i = interest rate
R = total years
t = individual years.

Because each of the annual costs **(C)** is different, we may wish to compute an average annual cost which, when discounted, would have the same present value as PV_{cost} in equation **(1).** If we let r be the equal annual equivalent cost, then:

$$r = [(PV_{cost})\ (i)\ (1+i)^R]/[(1+i)^R - 1]. \qquad (2)$$

Note that the equal annual equivalent cost computed with equation **(2)** is not the simple average of the projected costs. The simple average of projected costs would misstate the true economic consequences of fire management.

A team of **USDA** Forest Service fire and fuel specialists developed a table (on file, Forest Residues and Energy Program, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon) of value of damage and cost of suppressing wildfire, using costs for their area as a benchmark for a medium site, slope class **2,** and access category II (see Glossary for definitions). The land was forested, so figures reflect costs that would result from wildfire on timbered land. Open brushlands or grasslands would naturally have different suppression costs and damage values. Each area would have to be evaluated according to the resources present. The team derived costs above and below using their best judgment and available cost information. Because their figures apply to northwestern Oregon, we adjusted the values to reflect costs for the forests in our study for **1970-79** (table **2).** Values are categorized for various sites, slope classes, and accessibilities. The combined values for wildfire costs and resource damage are used for comparing various land capabilities and management options.

Table 2—Value (per burned acre) of damage and suppression costs for sites, slope classes, and access classes

Site	Slope class	Damage value	Access class	Suppression costs	Total
		Dollars		- - - Dollars - - - -	
High	3	714	III	6,512	7,226
			II	4,477	5,191
			I	2,664	3,378
	2	544	III	5,106	5,650
			II	3,071	3,615
			I	1,295	1,839
	1	425	III	3,848	4,273
			II	2,294	2,719
			I	1,036	1,461
Medium	3	425	III	2,294	2,719
			II	1,295	1,720
			I	1,036	1,461
	2	340	III	1,554	1,894
			II	740	1,080
			I	518	858
	1	289	III	1,036	1,325
			II	629	918
			I	518	807
Low	3	238	III	1,036	1,274
			II	777	1,015
			I	629	867
	2	153	III	777	930
			II	518	671
			I	370	523
	1	34	III	629	663
			II	370	404
			I	259	293

Perspective on Land-Management Plans and Cost Tables

Although wildfire statistics must be specific for areas or individual forests, cost and damage tables need not be *so* localized. For broad land-management planning, only relative costs and values for different management options need be compared—either on a regional, area, or forest basis, whichever reflects costs for the planning area. We used costs for Planning Area V.

Development of the Protection Cost Table

Protection costs are given for three access classes—(I) roaded, (II) modified, and (111) remote—and four fire-behavior classes (table 3). Access class II and fire-behavior class 2 were used as a base at $1.75 per acre (1979 dollars). These protection costs were derived from the average cost of protecting the mix of lands in the Region by studying the high and low protection costs, and by estimating the fire-fighting resources and associated costs of protecting a full management unit comprised of one access class and one fire-behavior class.

Table 3—Protection costs per protected acre per year, Pacific Northwest Region

Access class	Fire-behavior class			
	1	2	3	4
	Dollars			
I	1.00	1.50	2.00	2.50
II	1.25	1.75	2.25	2.50
III	1.50	2.00	2.50	2.50

Development of the Fuel-Treatment Cost Table

Table 4 was formed by using costs for various fuel treatments, assuming they represent the moderate difficulty presented by slope class 2. Variations from these averages resulted in costs above and below slope class 2.

Examples of Management Options

Table 4—Treatment cost per acre (1979 dollars) 1/

Treatment 2/	Slope class	Access class I	II	III
YUM	1	375	500	1,000
	2	350	700	1,200
	3	400	800	1,400
HPB	1	370	400	430
	2	400	430	460
	3	430	450	500
MPB	1	330	--	--
	2	--	--	--
	3	--	--	--
BB	1	200	250	--
	2	250	300	--
	3	300	350	--
UB	1	250	300	350
	2	300	350	400
	3	350	400	450
L&S	1	150	175	250
	2	175	200	275
	3	200	225	300
Crush	1	350	--	--
	2	--	--	--
	3	--	--	--
Air curt	1	1,000	--	--
	2	1,000	--	--
	3	1, 100	--	--
Pres fire	1	50	75	150
	2	75	100	200
	3	100	150	250

-- = machines cannot operate in these slope and access classes.

1/For visual management I areas, add 50 percent of handpile-and-burn cost to any treatment selected.

2/YUM = Yard unmerchantable material
HPB = Hand pile and burn
MPB = Machine pile and burn
BB = Broadcast burn
UB = Underburn
L&S = Lop and scatter
Air curt = Burning with air curtain or similar equipment
Pres fire = Prescribed fire other than BB and UB.

To enable the fire planner to project consequences, information on each management option should include:

- Planned timber rotation or expected vegetation cycle, in years.
- Timber-management prescription planned, what kind and at what point in the rotation (for example, precommercial thinning at 20 years, partial cut at 80 years, and harvest cut at 120 years).
- Access planned by one of three broad classes; roaded, modified, or remote.
- Visual standard expected, such as full retention, partial retention, and so on—as expressed in USDA Forest Service terminology.
- Expectations and constraints on use of prescribed fire—when in the cycle or rotation fire would be used, and what are the recommended intensities (minimum-maximum flame lengths).
- Expected change in public use during the cycle.

Two land-management alternatives formed from actual ones are the basis for the cost-loss examples in the succeeding sections of this report.

1. Wilderness management.
- 400-year vegetative cycle.
- No timber removal or culture.
- Trail access only.
- Full retention of natural visual qualities.
- No prescribed fire proposed.
- Public recreation use expected to triple during cycle.

2. Timber management.
- 275-year vegetative cycle (rotation).
- Cutting and cultural activity:
  - Precommercial thinning at 20th year.
  - Commercial thinning at 80th year.
  - Commercial thinning at 120th year.
  - Harvest cut at 275th year.
- Conventional road system planned.
- Visual requirement is background.
- Slash treatment by burning—either pile and burn or broadcast burn after each cutting entry.
- Public use expected to double during rotation.

Projecting Fire-Behavior Ratings for Management Options

To project the fire-behavior rating for each management option through a full cycle of management on each of three slope classes, we evaluated:

- Vegetation progression for broad local land types.
- Time in each stage of progression, fuel conditions, and behavior associated with each stage.
- Effects of cutting, cultural work, and fuel treatment on fire behavior.

Fire-behavior ratings for the wilderness were projected (fig. 2). On the Siskiyou National Forest, this option is generally considered for the high-elevation mixed-conifer type.

Note for slope class 1 on figure 2:

- Fire behavior is expected to be class 3 from year 0 to year 60 during the seedling-sapling stage. Such young stands are usually found growing through the heavy dead-and-down remnants of the preceding stand.
- Fire behavior is expected to be class 2 from year 60 to year 160. During this stage, shading tends to provide a moist microclimate but natural mortality of many pole-sized stems results in a fair amount of dead-and-down fuel.
- Fire behavior is expected to drop to class 1 from year 160 to year 320. This stage is represented by thrifty, full-crowned stands that shade the forest floor. Little residue is contributed from the standing trees. Decay of dead-and-down material is favored.
- Fire behavior is expected to rise to class 2 from year 320 to year 370 because of senescence and death of old-growth trees, which drop from the stand, open the canopy, and add to fuel.
- Fire behavior is expected to rise to class 3 from year 370 to year 400. Old-growth mortality is occurring at an accelerated rate, creating heavy ground fuel and exposure of these fuels to wind and sunlight.

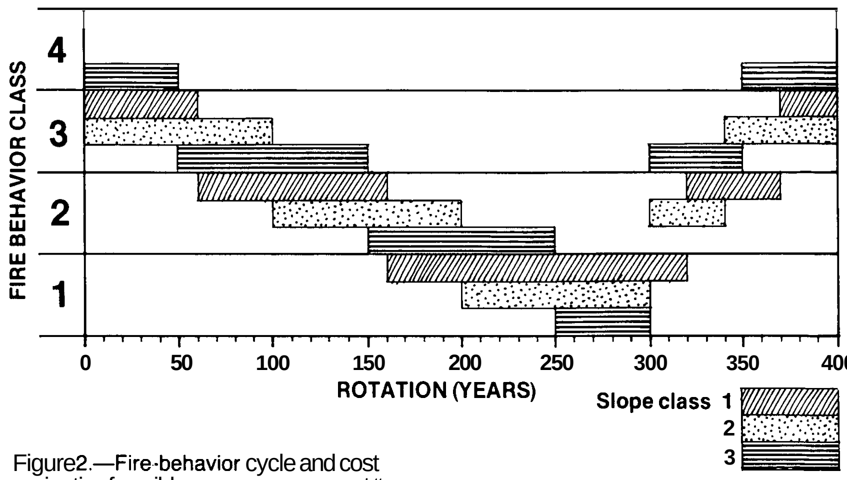

Figure 2.—Fire-behavior cycle and cost projection for wilderness management (low-intensity) option with a 400-year cycle, access class III.

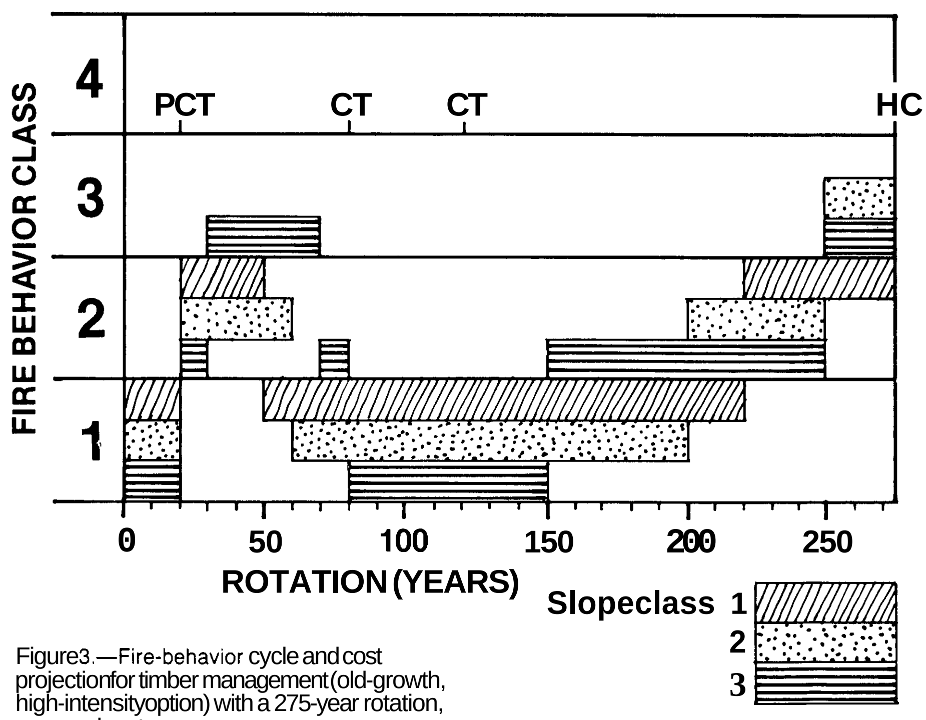

Figure 3.—Fire-behavior cycle and cost projection for timber management (old-growth, high-intensity option) with a 275-year rotation, access class I.

Considering these stages of vegetative progression and projected fire-behavior ratings for slope class 1 areas, we made similar projections for areas in slope classes 2 and 3.

The fire-behavior projection for the timber-management option was made in the same fashion as for the wilderness (fig. 3). On the pilot-test area, this timber option would generally be considered for better sites that would support full-crowned stands of ponderosa pine and associated species, or mixed conifer. To project fire behavior for this management option, we note points in the cycle where cutting entries are proposed—precommercial thinning (PCT), commercial thinning (CT), and harvest cut (HC). We also assumed that an appropriate residue treatment would be performed after each of these cutting entries.

Planners using this procedure for projecting fire behavior through a cycle of management will find photo series publications on the activity and natural residue levels, and companion fire-behavior tables, valuable (Blonski and Schramel 1981; Fischer 1981a, 1981b, 1981c; Koski and Fischer 1979; Maxwell and Ward 1976a, 1976b, 1979, 1980; Sandberg and Ward 1981; Ward and Sandberg 1981a, 1981b).

Projecting Costs for Protection and Fuel Treatment

Calculations of costs for fire protection and fuel treatment were made (tables 5 and 6). Note that graph projections in slope class 1 show fire behavior through the cycle is expected to be at class 3 for 90 years, at class 2 for 150 years, and at class 1 for 160 years.

Applying protection costs from table 3, and using the present value and equal annual payment formulas at 6-percent interest, the costs were:

90 years at $2.50 per year;
150 years at $2.00 per year; and
160 years at $1.50 per year.

Discounting these values to the present gives:

$PV_1 = (2.50/.06)\,[(1.06^{90}-1)/1.06^{90}]$
$= \$41.45.$
$PV_2 = [2.00/((.06)1.06^{90})]\,[(1.06^{150}-1)$
$/1.06^{150}] = \$0.18.$
$PV_3 = [1.50/((.06)1.06^{240})]\,[(1.06^{160}-1)$
$/1.06^{160}] = \$0.00002.$
$PV_1 + PV_2 + PV_3 = \$41.63.$

The equal annual payment calculation is:

$r = [(41.63)(.06)]/[(1.06^{400})/(1.06^{400}-1)]$
$= \$2.50$ per acre per year.

The same calculations were made for slope classes 2 and 3 (table 5). No calculations were made for fuel treatment because the management option did not propose any prescribed burning or other fuel work.

Fire-behavior classes for the timber-management (high intensity) option, based on graph projections (fig. 3), show—for slope class I — that fire behavior will not reach class 3 during the rotation, will be at class 2 for 85 years, and at class 1 for 190 years. Applying costs from table 4 gave:

0 years at $2.00 per year;
85 years at $1.50 per year; and
190 years at $1.00 per year.

Discounted to the present, the values are:

$PV_1 = 0.$
$PV_2 = (1.50/.06)\,[(1.06^{85}-1)/1.06^{85}]$
$= \$24.82.$
$PV_3 = [1.00/((.06)1.06^{85})]\,[(1.06^{190}-1)$
$/1.06^{190}] = \$0.12.$
$PV_1 + PV_2 + PV_3 = \$24.94.$

The equal annual payment for this option was:

$r = [24.94(.06)]/[(1.06^{275})/(1.06^{275}-1)]$
$= \$1.50.$

Similar calculations were made for slope classes 2 and 3.

This management option called for fuel treatment after each entry.

Table 5—Protection costs (1979 dollars) and projected percent of cycle ≥ fire-behavior class 3 for wilderness management cycle shown in figure 2

Fire-behavior class	Slope class	Time	Cost per acre per year (from table 3)	Cost per acre per year for all fire-behavior classes	Time in fire-behavior class ≥ 3	Portion of cycle
		Years	Dollars	Dollars	Years	Percent
3	1	90	2.50	2.50 1/	90	22.5
2		150	2.00			
1		160	1.50			
3	2	160	2.50	2.50	160	40.0
2		140	2.00			
I		100	1.50			
4	3	100	2.50	2.50	250	62.5
3		150	2.50			
2		100	2.00			
1		50	1.50			

1/ Remember, these are the equal annual payment costs after being discounted to the present.

Table 6—Protection and treatment costs (1979 dollars) and projected percent of cycle ≥ fire-behavior class 3 for timber-management cycle shown in figure 5

Fire-behdvior class	Slope class	Time	Protection costs (per acre): Cost per year (from table 3)	Protection costs (per acre): Cost per year for all fire-behavior classes	Silvicultural treatment	Residue treatment	Treatment costs (per acre): Cost	Treatment costs (per acre): cost per year	Time in fire-behavior class ≥ 3	Portion of cycle
		Years	Dollars	Dollars			Dollars	Dollars	Years	Percent
3		0	2.00		PCT	HPB	370			
2	1	85	1.50	1.50 1/	CT	MPB	660	7.13	0	0
1		190	1.00		H	BB	200			
3		25	2.00		PCT	HPB	400			
2	2	90	1.50	1.88	CT	HPB	800	7.73	25	9.1
1		160	1.00		H	BB	250			
3		65	2.00		PCT	HPB	430			
2	3	120	1.50	1.99	CT	HPB	960	8.34	65	23.6
1		90	1.00		H	BB	300			

1/ These are the equal annual payment costs after being discounted to the present.

Entries proposed are one precommercial thinning (PCT), two commercial thinnings (CT), and a harvest cut (HC). Based on cost, desirability, and practicality, a method of treatment to follow each entry was identified. These were, for slope class 1:

- After PCT, hand pile and burn.
- After CT, machine pile and burn.
- After the final harvest, broadcast burn.

Calculations for this treatment work, using costs from table 3, is:

PCT at $370 per acre;
CT at $660 per acre ($330 for two CT);
and HC at $200 per acre.

Discounting these values to the present would give:

$$PV = 370/(1.06)^{20} + 330/(1.06)^{80} + 330/(1.06)^{120} + 200/(1.06)^{275} = \$118.79.$$

The equal annual payment would be $7.13.

Similar calculations were made for slope classes 2 and 3 (table 6).

Projecting Wildfire Costs and Losses

The form "Fire in Land Management Planning" (fig. 4) was designed to aid in calculating projected costs and losses from wildfire for a management option practiced on three site categories within each of the three slope classes.

Wilderness Management Option

Figure 5 shows the completed calculation of cost and loss for the wilderness option. The fire-behavior classes of fuels in all of area V were believed to be the same proportions as those in the pilot-test area. Table 1 shows that 17 percent of the planning area currently is in critical fire-behavior classes 3 and 4. Sample information was recorded at the top of the form. Next, the percentages of acres lost per year listed by cause of fire (table 1) were transferred to the form on lines 1, 2, and 3: lightning, 0.00176 percent; industrial, 0.00931 percent; and public use, 0.00581 percent. Changes in risk of fire starts related to management option and expected future use (cutting and noncommercial use) were reviewed to determine risk factors. Because risk from lightning is unchanged by either management option or expected use, no factor column is provided on the form. No industrial entries were permitted by this management option, *so* the risk factor in line 4 was zero and the adjusted loss from industrial causes, line 6, became zero. Expected public use was expected to triple, *so* a factor of 3 in line **5** was used to adjust the 0.00931 in line **3** to 0.01743 in line 7. Expected losses from risk were then summed to 0.01919 percent on line 8, the adjusted percent burned per year because of changes in risk.

Change in expected loss to wildfire, from potential change in fire behavior brought about by the management option, was determined by first analyzing table 5. This revealed that during the cycle, fuels in slope class 1 would be in fire-behavior classes 3 and 4 for 22.5 percent of the time, slope class 2 in behavior classes 3 and 4 for 40 percent of the time, and slope class 3 in behavior classes 3 and 4 for 62.5 percent of the time. These results were entered in lines 9, 10, and 11.

Most acres lost to wildfire were in fire-behavior classes 3 and 4. Because 17 percent of area V was in fire-behavior classes 3 and 4, this percent was divided into the percentages of 22.5, 40.0, and 62.5 to arrive at the fire-behavior factors of 1.3235, 2.3529, and 3.6765, shown in lines 12, 13, and 14.

The adjusted acreage burned (risk percentage) from line 8 was then further adjusted by the fire-behavior factors from lines 12, 13, and 14, to produce the expected percentage of loss from wildfire for the three slope classes (lines 15, 16, and 17).

Appropriate cost-loss values from table 2 were entered in column 21. Note that this example area is in access class III (remote), and three site categories within each slope class are considered. Lines 15, 16, and 17 percentages were divided by 100 and then multiplied by the cost-loss value in column 21 to produce the column 22 cost-loss figures, which are dollars of cost-loss per acre managed under this management option, depending on slope class and site category.

Column 23 displays, by three slope classes, the expected percentage of loss to wildfire during a full cycle for lands managed under this option. This projection was made by multiplying the annual loss estimate (column 18) by the years in the planned cycle.

Timber Management Option

Figure 6 shows the completed calculation for this management option. As with the previous example, annual percentages of wildfire loss by broad causes were entered in lines 1, 2, and **3.** This option calls for four cultural or cutting entries in the stand during the cycle. A risk factor of four was therefore used in line 4. Noncommercial use under this option is expected to double in the next cycle, so a factor of two was used in line 5. The projection, because of risk given in line 8, is 0.05062 percent. Fire-behavior percentages were obtained from table 6. The balance of the calculations for this example followed the same procedure as used for the previous example.

Planning option ______________________ Planning unit ______________________

Specific practice ______________________

Accessibility class __________ Percent area in fire behavior (FB) ≥ class 3 __________

Visual management code ______________ Rotation (years) __________

Fire management ______________________

Projected use ______________________

RISK CALCULATION

Percent area burned from:

Lightning	1. ______	Risk factor: Industrial use	4. ______
Industrial use	2. ______	General public use	5. ______
General public use	3. ______		

Adjusted area burned:

6. ______ (2 x 4) 7. ______ (3 x 5) 8. ______ (1 + 6 + 7)

FIRE-BEHAVIOR CALCULATION

	Slope class 1	2	3
Projected percent of cycle ≥ fire-behavior class 3	9. ______	10. ______	11. ______
Fire-behavior factor	12. ______ (9 ÷ FB)	13 ______ (10 ÷ FB)	14. ______ (11 ÷ FB)
Expected loss per year	15. ______ (8 x 12)	16. ______ (8 x 13)	17. ______ (8 x 14)

COST-LOSS CALCULATION

18. Expected loss per year	19. Slope class	20. Site	21. cost-loss value per acre (from table 2)	22. cost-loss coefficient per acre $\left(\frac{18 \times 21}{100}\right)$	23. Projected percent loss per cycle $\left(\frac{18 \times \text{years}}{\text{in cycle}}\right)$
		High	______	______	
15. ______	1	Med.	______	______	______
		Low	______	______	
		High	______	______	
16. ______	2	Med.	______	______	______
		Low	______	______	
		High	______	______	
17. ______	3	Med.	______	______	______
		Low	______	______	

Figure 4.—Form for evaluating fire in land-management planning.

Planning option WILDERNESS Planning unit ILLINOIS VALLEY
Specific practice WILDERNESS
Accessibility class III Percent area in fire behavior (FB) ≥ class 3 17
Visual management code PRESERVATION Rotation (years) 400
Fire management SUPPRESS ALL FIRES AND NO PRESCRIBED BURNING
Projected use PUBLIC USE EXPECTED TO TRIPLE

RISK CALCULATION

Percent area burned from:

Lightning 1. 0.00176
Industrial use 2. 0.00931
General public use 3. 0.00581

Risk factor: Industrial use 4. 0
General public use 5. 3

Adjusted area burned:

6. 0 (2 x 4) 7. 0.01743 (3 x 5) 8. 0.01919 (1 + 6 + 7)

FIRE-BEHAVIOR CALCULATION

	Slope class 1	2	3
Projected percent of cycle ≥ fire-behavior class 3	9. 22.5	10. 40.0	11. 62.5
Fire-behavior factor	12. 1.3235 (9 ÷ FB)	13 2.3529 (10 ÷ FB)	14. 3.6765 (11 ÷ FB)
Expected loss per year	15. 0.02540 (8 x 12)	16. 0.04515 (8 x 13)	17. 0.07055 (8 x 14)

COST-LOSS CALCULATION

18. Expected loss per year	19. Slope class	20. Site	21. cost-loss valde per acre (from table 2)	22. Cost-loss coefficient per acre $\left(\frac{18 \times 21}{100}\right)$	23. Projected percent loss per cycle (18 X years in cycle)
		High	4,273	1.09	
15. 0.0254	1	Med.	1,325	0.34	10.2
		Low	663	0.17	
		High	5,650	2.55	
16. 0.0452	2	Med.	1,894	0.86	18.1
		Low	930	0.42	
		High	7,226	5.10	
17. 0.0706	3	Med.	2,719	1.92	28.2
		Low	1,274	0.90	

Figure 5.—Sample form showing wilderness planning option.

Planning option TIMBER MANAGEMENT Planning unit ILLINOIS VALLEY

Specific practice TIMBER HARVEST

Accessibility class ______ Percent area in fire behavior (FB) ≥ class 3 17

Visual management code BACKGROUND Rotation (years) 275

Fire management TREAT RESIDUE AFTER EACH ENTRY

Projected use WOODCUTTING, CAMPING, HUNTING TO DOUBLE

RISK CALCULATION

Percent area burned from:

Lightning	1. 0.00176	Risk factor: Industrial use	4. 4
Industrial use	2. 0.00931	General public use	5. 2
General public use	3. 0.00581		

Adjusted area burned:

6. 0.03724 (2 x 4) 7. 0.01162 (3 x 5) 8. 0.05062 (1 + 6 + 7)

FIRE-BEHAVIOR CALCULATION

	Slope class 1	2	3
Projected percent of cycle ≥ fire-behavior class 3	9. 0	10. 9.1	11. 23.6
Fire-behavior factor	12. 0 (9 ÷ FB)	13 0.5353 (10 ÷ FB)	14. 1.3882 (11 ÷ FB)
Expected loss per year	15. 0 (8 x 12)	16. 0.02710 (8 x 13)	17. 0.07027 (8 x 14)

COST-LOSS CALCULATION

18. Expected loss per year	19. Slope class	20. Site	21. cost-loss value per acre (from table 2)	22. cost-loss coefficient per acre $\left(\frac{18 \times 21}{100}\right)$	23. Projected percent loss per cycle (18 x years in cycle)
		High	1,461	0	
15. 0	1	Med.	807	0	0
		Low	293	0	
		High	1,839	0.50	
16. 0.02710	2	Med.	858	0.23	7.5
		Low	523	0.14	
		High	3,378	2.37	
17. 0.07027	3	Med.	1,461	1.03	19.3
		Low	867	0.61	

Figure 6.—Sample form showing timber-management planning option.

Assembly of Cost-Loss Projections

Example 1 in figure 7 assembles, for the wilderness management option, projections of protection and fuel treatment from tables 5 and 6, suppression and damage values, and percent lost to wildfire per cycle from figure 5. These are shown separately, for convenience.

Example 2 in figure 7 assembles like projections for the timber option.

Example 1--Wilderness

Protection
Slope class 1 = $2.50
Slope class 2 = $2.50
Slope class 3 = $2.50

Fuel treatment -- None

Suppression and damage (per planned acre per year)

Slope class 1 site	High	$1.09
	Medium	$0.34
	Low	$0.17
Slope class 2 site	High	$2.55
	Medium	$0.86
	Low	$0.42
Slope class 3 site	High	$5.10
	Medium	$1.92
	Low	$0.90

Percent of area lost to wildfire per cycle
Slope class 1 = 10.2%
Slope class 2 = 18.1%
Slope class 3 = 28.2%

Example 2--Timber harvest

Protection
Slope class 1 = $1.50
Slope class 2 = $1.88
Slope class 3 = $1.99

Fuel treatment
Slope class 1 = $7.13
Slope class 2 = $7.73
Slope class 3 = $8.34

Suppression and damage (per planned acre per year)

Slope class 1 site	High	$0.00
	Medium	$0.00
	Low	$0.00
Slope class 2 site	High	$0.50
	Medium	$0.23
	Low	$0.14
Slope class 3 site	High	$2.37
	Medium	$1.03
	Low	$0.61

Percent of area lost to wildfire per cycle
Slope class 1 = 0.0%
Slope class 2 = 7.5%
Slope class 3 = 19.3%

Figure 7.—Summary of cost-loss for two management options.

Study Assumptions

Statistics on Causes of Wildfire and Area Burned

We believe statistics on causes of wildfire and area burned should be taken from the current decade if they are to reflect current risks and effectiveness of suppression. Such statistics for a small area, however, do not provide a sound base because fire occurs sporadically and behaves erratically. We therefore used wildfire statistics for the whole USDA Forest Service Region 6 planning area.

Use of area wildfire statistics required estimating amounts of fuels critical to fire-behavior (classes greater than or equal to 3). We used a fire-behavior map for the pilot-test area to make a comparative estimate of critical fuels in the area.

The area V statistics on wildfire and the proportion of fuels in the critical category were used to make the projections on loss from changes in fuel conditions and fire-behavior classes attributable to management.

Users of this procedure will want to be assured that the percentage of fuels falling in the critical fire-behavior class is derived from the same area as the wildfire statistics.

Wildfire and Critical Fuels

Critical fuels in the study were considered to be those in fire-behavior classes 3 and **4,** as rated in Part 2 of this study. These are fuels with an expected spread rate greater than or equal to 8.5 chains per hour or flame lengths greater than or equal to 7.5 feet.

We believe fires in lower behavior classes can generally be controlled when small and that fires escaping control and consuming large areas generally do so where critical fuels are present. Projections of wildfire loss related to management option are therefore based on critical fuels produced by the management option over time.

Risk Projections

Expected increases in industrial entries and public use vary with management options. We believe that current fire-prevention programs are relatively sophisticated and, although they would expand to meet increasing risks, they would not necessarily be more effective. A directly proportionate risk factor for expected increase was therefore used in the study examples.

Users of the procedure may wish to change factors for risk based on their own insights. They may decide, for example, that a management option that anticipates a doubling of public use would likely result in a risk factor of 1.5 rather than 2.0, indicating a commensurate increase in effective measures for fire prevention is on the horizon.

Metric Conversion

Multiply	by	To obtain
Acres	0.4047	hectares
Feet	0.3048	meters
Chains	20.1168	meters

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Glossary

Access Classes

Roaded areas (class I) would have a conventional road system. A modified area (class II) would require logging by long skylines, balloon, or helicopter, or would, for management reasons, have a restricted conventional road system and require short hiking distances for forest users and managers. A remote area (class III) would require long hiking distances, such as in a wilderness.

Fire-Behavior Classes

Fire-behavior class	Rate of spread	Flame length
	Feet/minute	*Feet*
1	0-2.4	0-3.4
2	2.5-8.4	3.5-7.4
3	8.5-29.4	7.5-11.4
4	29.5 +	11.5 +

The higher of the two fire-behavior factors determines the fire-behavior class rating.

Site Classes

Low – thin, rocky soils generally found on ridgetops or steep slopes. Restocking is not adequate, and the potential for timber yield is low.

Medium – more productive soils than low class, with soils depths 1 to 2 feet. Generally found on gentle slopes with adequate restocking and good potential for timber yield.

High – deep, fertile soils generally found on valley or canyon bottoms. Restocking potential is excellent with a high annual timber yield.

Note: These definitions are purposely stated in general terms. The land manager may need to redefine these site categories to reflect local conditions.

Slope Classes

Slope class	Percent slope
1	0 - 30
2	31 - 60
3	61 +

Maxwell, Wayne G.; Sandberg, David V.; Ward, Franklin R. Fuels and fire in land-management planning: Part 3. Costs and losses for management options. Gen. Tech. Rep. PNW-158. Portland, OR: U.S. Department of Agriculture, forest Service, Pacific Northwest Forest and Range Experiment Station; **1983.18** p.

An approach is illustrated for computing expected costs of fire protection; fuel treatment; fire suppression; damage values; and percent of area lost to wildfire for a management or rotation cycle. Input is derived from Part 1, a method for collecting and classifying the total fuel complex, and Part 2, a method for appraising and rating probable fire behavior. This approach can be used locally for fire management and in land-management planning.

Keywords: Fire management, fuels (forest fire), fire behavior (forest), fire planning, management planning (forest).

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