USING PRESCRIBED FIRE TO REDUCE THE RISK OF LARGE WILDFIRES: A BREAK-EVEN ANALYSIS[1]

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1. INTRODUCTION

Nearly all wildfires are extinguished when they are still small. The 3-5% that get out of control cause 95% of all wildfire-related costs and damages (Dodge 1972, Wilson 1985). There are two ways to deal with these problem fires. One practice is to limit fire by suppressing fires as soon as possible after they are detected. Increasing the capability of suppression forces would presumably allow fire-fighters to catch more large fires when the fires are still small. However, substantial increases in suppression capability occurred in the 1970's without a reduction in suppression expenditures and fire losses (Gale 1977). Increased appropriation of funds for fire exclusion has not reduced values at risk or area burned (Bonnicksen and Lee 1979). The other practice is to use prescribed fire to reduce the fire hazard. Every management area relies to varying degrees on one or both of these management practices. Both practices modify the role of fire in the ecosystem, thus changing the set of possible outcomes and their probabilities (Zivnuska 1977).

Human suppression activities may actually increase the probability of large, severe wildfires. For example, in spite of suppression efforts in chaparral, severe wildfires continue to burn large areas (Minnich 1983). Large, severe burns may not have been characteristic of fires before the initiation of suppression (Minnich 1983). In ponderosa pine communities, fire return intervals have increased, but large, severe fires are more common (Steele et al. 1986). Fewer, large crown fires are replacing several, small surface fires. Occasional escaped fires in short return interval ecosystems, such as ponderosa pine, tend to be more severe and may reduce or eliminate open stands of old dominant seral species (Brown 1985). After several years of suppression, the potential exists for a severe crown fire to convert a ponderosa pine cover type to Douglas-fir (Arno et al. 1985).

In contrast, prescribed fire may decrease the probability of large, severe wildfires (Biswell 1967, Weaver 1964). Prescribed burning reduced the average size of wildfires in ponderosa pine in Arizona (Knorr 1963), and prescribed fires effectively reduced the number, size, and intensity of wildfires in the southeast (Davis and Cooper 1963). My own observations of fires in the Selway-Bitterroot Wilderness of central Idaho concur with Sweaney's (1985) observations in Yellowstone National park that old burns limit the size of future fires.

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The reason that suppression activities increase the probability of large, severe wildfires is fuel accumulation and increased fuel continuity, especially development of ladder fuels (Dodge 1972). Ladder fuels carry fire from the surface into the tree crowns. When there is no periodic energy loss through burning, there can be a large energy build up (Van Wagtendonk 1985). Instability results when fire is removed from fire-dependent plant communities (Van Wagner and Methven 1980, Van Wagtendonk 1985).

Prescribed fire has usually been limited to fuels created by logging activities. Applying prescribed burning to natural fuels might further reduce the risk of large, severe wildfires. Wood (1979) examined the economic feasibility of managing natural fuels in mature timber to reduce costs and damages of wildfire. He concluded that fuel treatment (such as prescribed fire) to protect timber alone was not economically feasible on the Lolo National Forest in Montana, but may be justified if treatment enhances other forest values. Fuel treatment was not economically feasible because of high treatment costs, low fire occurrence, and low timber values (Wood 1979).

This paper takes a related, but somewhat different approach. Fire management is in many ways synonymous with risk management. Managers are increasingly aware of the need to know how management actions will affect the probability of large escaped wildfires occurring and the magnitude of costs associated with such fires. Management actions such as rapid initial attack, use of prescribed fire, and use of an escaped fire situation analysis will presumably affect the probability of future fire occurrence and the magnitude of costs. This paper examines the monetary tradeoffs of investing in a prescribed fire program in natural fuels to reduce the probability of large, costly fires.

2. BREAK-EVEN ANALYSIS

Should money be invested in a prescribed burning program in natural fuels in an effort to prevent large, costly fires (costly in terms of resource damage or actual monetary expenditures)? If the answer is yes, how much money should be invested? A break-even analysis can help answer these questions. The analysis developed here is based on the formula for an infinite periodic series and the formula for a perpetuity. Namely,

infinite periodic series $$NPC = \frac{a}{(1+e)^r - 1}$$

perpetuity $$NPC = \frac{b}{e}$$

where,

NPC = net present costs
a = amount of money spent every r years for suppression of large wildfires
b = amount of money spent each year for prescribed burning
r = return interval of large, costly fires
e = the effective discount rate (real rate adjusted for increasing costs)

$$e = \frac{1 + i}{1 + g} - 1$$

where,

i = real interest rate
g = real rate of increasing costs

A certain amount of money (a) is spent to suppress large fires occurring every r years. If r can be increased by an amount t through an annual prescribed burning program, what then is the amount of money (b) that one could spend for prescribed burning? That is, what is the break-even point? Algebraically, the solution for b is:

$$b = \left[\frac{a}{(1 + e)^{r} - 1} - \frac{a}{(1 + e)^{r+t} - 1}\right] \times e$$

The underlying assumption of this analysis is that management practices will influence the return interval of large fires. Increasing the return interval is synonymous with decreasing the probability of a large, costly fire, because the return interval in the reciprocal of the probability of occurrence.

An example, using data from the Gospel-Hump Wilderness on the Nez Perce National Forest in central Idaho, will illustrate these relationships. Historical records show large fires (> 1000 acres) occurring about once every 8 years. Large fires along the Salmon River Breaks in the Gospel-Hump Wilderness can easily cost more than $1 million to suppress due to inaccessibility, steep terrain, and the large number of people required. Assume that $1 million are spent to suppress a large fire every 8 years. If there would have been 6 large fires in 48 years but prescribed burning eliminated one of those fires (giving 5 large fires in 48 years), then the return interval would shift from 8 to 9.6 years. The Forest Service uses a real interest rate of 0.04. Assume a real rate of increasing costs of 0.01 for an effective discount rate of 0.03. If one large fire is eliminated, extending the interval from 8 to 9.6, then:

$$b = \left[\frac{\$1{,}000{,}000}{(1.03)^{8} - 1} - \frac{\$1{,}000{,}000}{(1.03)^{9.6} - 1}\right] \times e$$

$b = \$21,026$

Thus, up to $21,026 could be spent annually in a prescribed burning program. If prescribed burning costs range from $5-$25/acre, 840 to 4,200 acres (340 to 1,700 ha) can be treated each year. The question for the decision maker becomes, will that amount of annual burning eliminate one large wildfire in 48 years (reduce the probability of a large wildfire from 0.125 to 0.104)?

If spending $15,000 a year in prescribed burning results in increasing the return interval of $1 million fires from 8 to 9.6 years, then the net decrease in annual costs is $6,026. The optimum amount of money to spend for prescribed burning is the least amount of money that will result in the greatest increase in the return interval. Spending too little will not change the return interval, and annual costs will increase. Conversely, spending too much will eventually result in small gains. Further research is needed to establish the production function that relates prescribed burning to the return interval (probability) of large, costly fires.

3. SENSITIVITY ANALYSIS

A sensitivity analysis revealed that the return interval of large, costly fires (r) and the amount the return interval is increased (t) are the most sensitive variables. As r increases, the amount of money one could spend in an annual prescribed burning program (b) decreases exponentially. As t increases, the amount of money one could spend increases exponentially. The amount of money spent suppressing large fires (a) is directly proportional to the amount of money one could spend annually on prescribed burning. If a doubles, then b doubles. In contrast to most economic analyses, the effective interest rate in relatively insensitive. Large changes in e will only produce small changes in b.

Large costly fires may occur, on the average, once every r years, but of course they do not occur precisely every r years. According to the properties of discounting, the closer to the present time a cost occurs, the higher the cost in present dollars. The smaller the variation of large fire occurrence from the mean, especially near the present, the closer the predicted costs are to actual costs. If the time interval varies substantially from the mean, r could be increased to be on the safe side.

4. DISCUSSION

The answer to the question of whether to invest money in prescribed burning is yes, from a financial viewpoint, if the average return interval of large, costly fires can be increased significantly. How much money can be invested depends on the amount spent suppressing large fires (a) and the average return interval before prescribed burning (r) and after prescribed burning (r + t). In areas where r is large to begin with, prescribed burning to further increase r would not be justified. In areas of high fire occurrence, where periodic, large, expensive fires are a certainty, prescribed burning would be cost effective.

This analysis does not consider the obstacles to overcome in trading off savings in emergency fire-fighting dollars for increased appropriated budgets. Nor does this analysis consider the larger question: What is the optimum level of investment in any form of fire management? Resource net value changes must be considered as well as costs if an efficiency analysis is to be performed.

Consider the following example. There are approximately 40,000 acres (16,200 ha) of ponderosa pine along the Salmon River Breaks in the Gospel-Hump Wilderness in central Idaho. The natural fire cycle is approximately 12.5 years. Attempting to imitate the natural fire cycle with prescribed fire requires burning an average of 3,200 acres (1,300 ha) per year. Burning costs average $5-$10 per acre, but to be on the conservative side, burning costs of $15 per acre will be used for the analysis. This means spending $48,000 each year. This seems like a lot of money. Is it a wise investment?

On the average, $1 million are spent to suppress a large fire every 8 years. Since a large fire does not occur exactly every 8 years, a conservative return interval of 10 years will be used for the analysis. Now suppose that, by returning the ecosystem to a more natural fire cycle by prescribed burning on a 12.5 year cycle, the probability of a large, costly fire occurring now is similar to that of a 100-year rain storm. The break-even point of reducing a $1 million fire from occurring once every 10 years to once every 100 years (reducing the probability from 0.1 to 0.01) is:

$$b = \left[\frac{\$1,000,000}{(1.03)^{10} - 1} - \frac{\$1,000,000}{(1.03)^{100} - 1}\right] \times e$$

$$b = \$85,584$$

One could spend up to $26/acre for prescribed burning costs. Spending $48,000 a year in prescribed burning translates into a savings of at least $37,584 a year. Think of the $48,000 as spending $1.20/acre/year to protect each acre from large, severe fires, as opposed to $1 million every 8 years or so, which translates into spending $2.81/acre/year to suppress large, severe fires. The larger question remains: Do the resource values justify additional protection costs of $1.20/acre/year?

In summary, management actions affect the probability of future events. Fire suppression activities without the use of prescribed fire may be increasing the probability of future, large, severe wildfires due to fuel accumulation and increased fuel continuity. The probability of a large, severe wildfire is a sensitive variable, yet these probabilities are seldom considered by managers. In addition, people have certain biases and limitations when dealing with probabilistic information (Kahneman et al. 1982, Wickens 1984). There is an opportunity for large financial gains in prescribed burning of natural fuels in critical areas. Further research is needed to determine the effect of prescribed burning on the magnitude of change of the probability of large, severe fires.

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