PREDICTION ERRORS IN WILDLAND FIRE SITUATION ANALYSES

Geoffrey H. Donovan and Peter Noordijk

Wildfires consume budgets and put the heat on fire managers to justify and control suppression costs. To determine the appropriate suppression strategy, land managers must conduct a wildland fire situation analysis (WFSA) when:

- A wildland fire is expected to or does escape initial attack,
- A wildland fire managed for resource benefits exceeds prescription parameters, or
- A prescribed fire exceeds its pre-scription and is declared a wildfire.

On large wildfires, land managers sometimes conduct five or more WFSAs.

Although the WFSA process is important and land managers are required to use it, research on the accuracy of WFSA predictions is lacking. We used data from the 2002 fire season to determine how WFSA-predicted outcomes compared to actual outcomes in terms of final fire size and suppression costs.

What Is a WFSA?

The WFSA process is not prescrip-tive. Instead, it is a decision analysis tool that requires land managers to evaluate different suppression strat-egies. There are three stages of a WFSA (MacGregor 2000):

1. Criteria for evaluating suppression alternatives are identified and mea-

Geoffrey Donovan is a research forester and Peter Noordijk is a research assistant, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

surable objectives are established. Criteria include firefighter safety, potential resource damage, and loss of private structures.

2. Plausible suppression alternatives are developed. All alternatives have a strategic plan focusing on firefighter and public safety, available resources, containment time, probability of success, final fire size, resource damages, and suppression costs.

3. Suppression alternatives are analyzed. Managers assess the compatibility of a suppression strategy with forest plan objectives, safety, and probability of success. Then they select the alternative that minimizes resource damages and suppression costs.

Managers use several variables and probability estimates to assign an overall score to alternative suppression strategies. The alternatives evaluated are typically associated with either the objective (minimizing fire size, suppression costs, and so on) or the suppression strategy (direct attack, indirect attack, and so on). Most WFSAs evaluate two or three different alternatives. For each alternative, users define a target and a worst-case outcome, and they might also define an intermediate fallback outcome. For each outcome, users estimate the probability, associated suppression costs and resource damages, final fire size, and objective score.

An objective score indicates how well a particular outcome meets a series of objectives. Although users can define their own objective categories, the default categories are safety, eco-

nomic, environmental, social, and other. For each alternative, users calculate an expected objective score by multiplying the probability of each outcome by its objective score, then summing the resulting scores. The expected suppression cost and resource damage are calculated in the same way. Users display estimates in a decision tree format (fig. 1).

Predicted Versus Actual Outcomes

We obtained data from the USDA's National Information Technology Center on fire size and suppression cost for 157 wildfires handled by type 1 and type 2 incident management teams during the 2002 fire season. Since WFSA data are not collected nationally, we contacted local land managers responsible for each of the 157 fires and requested their completed WFSAs. We received WFSAs for 49 fires-42 fires with only one WFSA and 7 with multiple WFSAs, for a total of 58 WFSAs. The 49 fires varied in size from 87 acres (35 ha) to about 151,000 acres (61,000 ha). The fires burned a total of almost 805,000 acres (326,000 ha) at a suppression cost of about $312 million, for an average per-acre suppression cost of about $388.

To determine the accuracy of WFSA probability estimates, we compared the estimated probability of target outcome success to the actual out-come. We asked two questions:

1. Was actual fire size smaller than target size?
2. Was actual suppression cost less than target cost?

Across all WFSAs, the mean estimated probability of success of the target outcome was 71 percent. Actual fire data showed that fire size was smaller than target fire size for 63 percent and actual costs were lower than target costs for 44 percent of the WFSAs. Fire managers often underestimated the probability of a given wildfire exceeding its target size and costs, although they were better at predicting fire size than costs.

> ## We used data from the 2002 fire season to determine how WFSA-predicted outcomes compared to actual outcomes.

We used a similar process to determine the accuracy of worst-case probability estimates. Across all

fires, the mean estimated probability of the worst-case outcome occurring was 16 percent. Actual fire data showed that fire size exceeded worst-case fire size by 7 percent and that actual costs exceeded worst-case costs by 19 percent. Fire managers tended to overestimate the probability of actual fire size exceeding worst-case size but to slightly underestimate the probability of costs exceeding worst-case costs.

The seemingly inconsistent results are perhaps attributable to how fire managers estimate suppression costs. We hypothesize that fire managers estimate suppression costs by first estimating fire size and then estimating per-acre cost, with suppression cost being a product of the two. To determine the accuracy of per-acre cost estimates, we compared actual, worst-case, and expected per-acre costs (fig. 2).

The differences between estimated worst-case and actual per-acre costs help explain why worst-case cost probability estimates are approximately correct. For fires smaller than 18,000 acres (7,300 ha)-39 of the 49 fires in our sample-worst-case per-acre costs underestimated actual per-acre costs. The tendency of fire managers to overestimate the probability of a fire exceeding its worst-case size is equivalent to overestimating fire size. If an over-estimated fire size is multiplied by an underestimated per-acre cost, the two errors in estimation usually cancel each other, making worst-case cost estimates approximately correct.

This hypothesis also explains why target cost estimates are less accurate than target size estimates. Figure 2 shows that for all fires, estimated target costs underestimate actual per-acre costs. The tendency of fire managers to underestimate the probability of a fire exceeding its target size is equivalent to under-estimating fire size. If an underestimated fire size is multiplied by an underestimated per-acre cost estimate, the result is a cost estimate that underestimates actual cost more frequently than target size underestimates actual size.

The data in figure 2 raise the question of why there is a difference in per-acre cost between target and worst-case outcomes. Fire size, fuel type, topography, weather, and resource availability can affect per-acre costs. However, why would labeling an outcome as target or worst-case affect per-acre costs? Such a classification is subjective and does not affect fire behavior, values at risk, or resource availability.
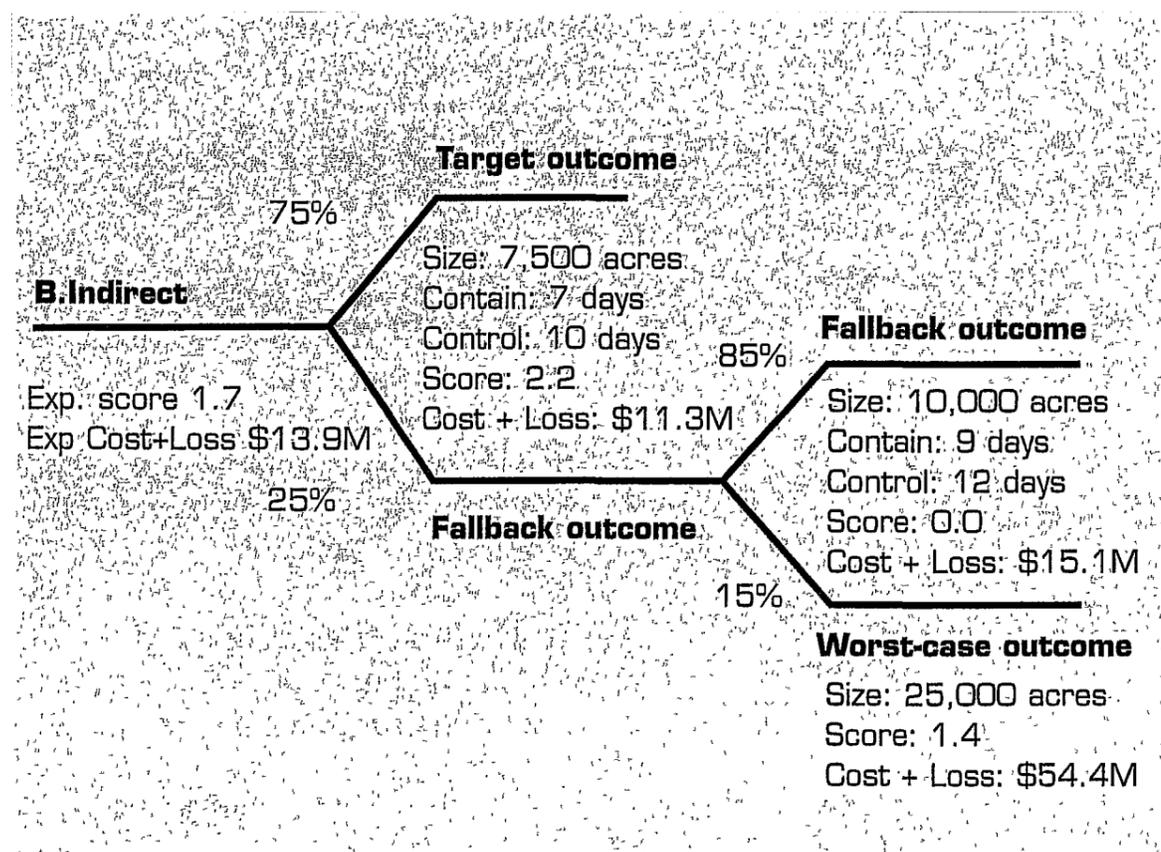
It appears that the optimism associated with target outcome estimates also affects per-acre cost estimates, which for the majority of fire sizes

Figure 1- *This wildland fire situation analysis decision tree was used to evaluate an indirect suppression strategy for the Grizzly Complex Fire in Lake County, OR. Other alternatives (such as A. and C.) included direct attack. Percentages are probabilities of realizing a particular outcome.*

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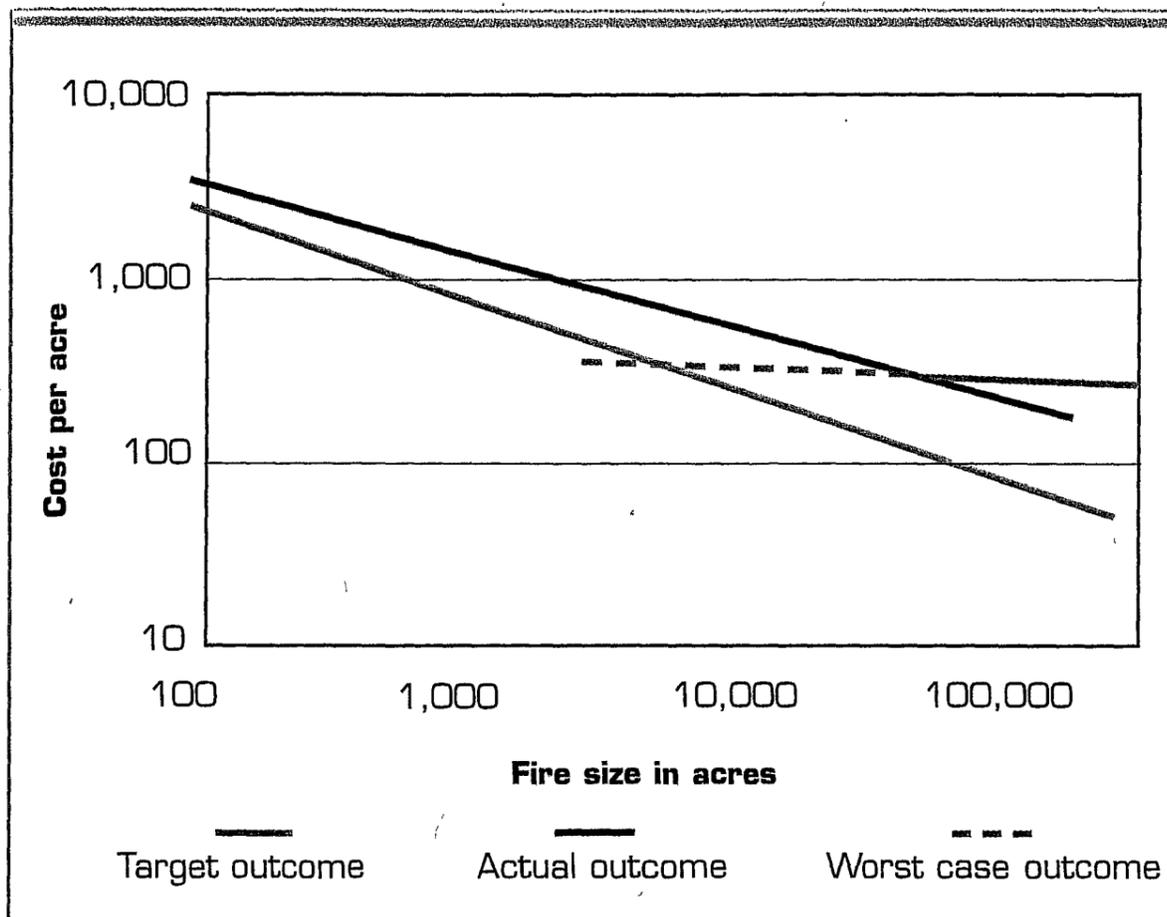

Figure *2-Per-acre costs as a function of fire size for target outcome, worst-case outcome, and actual outcome. The trend lines do not imply a strict linear relationship between per-acre costs and fire size. The general relationship between fire size and per-acre cost is sufficient; therefore, individual data points were excluded for clarity.*

are lower than worst-case per-acre cost estimates. In addition, target per-acre cost estimates decline more with increasing fire size than worst-case per-acre cost estimates. In contrast, worst-case per-acre cost estimates are higher and show little decline with increasing fire size.

Improving Estimates

Estimating probabilities is challenging. Our results are consistent with previous research showing that people tend to underestimate the probability of likely events occurring and overestimate the probability of unlikely events occurring. For

example, Lichtenstein and others (1978) asked people to estimate the frequency of various causes of death in the United States. Respondents consistently overestimated the probability of dying from unlikely causes such as tornadoes or food poisoning while consistently underestimating the probability of dying from likely causes such as heart disease or cancer.

Past research also suggests some possible ways to improve estimates. Baron (2000) has shown that when people first list the factors that they believe will influence the probability of an event occurring, their subsequent probability estimates are more accurate. Perhaps fire managers should first list factors that could influence the success of a particular strategy-such as weather, resource availability, and topography-before estimating the probability of the strategy succeeding. We also found that managers tend to estimate fire size more accurately than suppression costs. Using available historical per-acre fire costs might help improve suppression cost estimates.

References

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