

Nonmarket Resource Valuation in the Postfire Environment

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ABSTRACT

After the containment of large wildland fires, major onsite and downstream effects including lost soil productivity, watershed response, increased vulnerability to invasive weeds, and downstream sedimentation can cause threats to human life and property. Burned Area Emergency Response (BAER) teams are responsible for developing treatment plans to mitigate negative consequences associated with these postwildfire events. BAER teams are charged with demonstrating that proposed treatments are economically justified. When the resources at risk are market values this poses few challenges; however, when the resources at risk are nonmarket values serious challenges occur including limited supporting scientific research, a lack of economics expertise and training among BAER team members, and tight time frames for conducting assessments resulting in final assessments that may not be defensible. In this study we show a clear and reproducible valuation procedure termed implied minimum value that may be adopted by BAER teams to improve the economic justification of treatments proposed to protect nonmarket resource values.

Keywords: nonmarket valuation, postfire environment, Burned Area Emergency Response (BAER)

Increased wildfire activity in the United States over the last 10 years and the associated cost with managing these events has had profound effects on the budgets of public land management agencies such as the US Forest Service, USDA (USFS), and several agencies within the US Department of Interior (USDOI). All aspects of the agencies' fire management programs have come under increased scrutiny regarding their ability to control costs and provide value (USDA Office of Inspector General 2006). After the containment of large wildland fires, major onsite and downstream effects including lost soil productiv-

ity, watershed response, increased vulnerability to invasive weeds, and downstream sedimentation causing threats to human life and property can occur (Robichaud et al. 2000). We broadly define these negative consequences as postfire effects, whereas we use the term postfire event, frequently a major rainfall event, to identify the occurrence that triggers these effects. After wildfires, US Forest Service and DOI Burned Area Emergency Response (BAER) teams evaluate the likelihood of damaging postfire events occurring and, if conditions warrant, recommend immediate actions, such as land treatments, road improvements, and warning

systems to mitigate the potential impacts of the identified threats. Emergency treatments recommended by the assigned BAER team are then forwarded to the local land manager for approval. If the recommended treatment program exceeds identified cost thresholds, additional approval at the regional or national level may be required.

BAER teams are charged with economically justifying proposed treatment projects. This requires identifying the cost of proposed treatments and the expected benefits of those treatments (computed as the reduction of value loss to protected resources multiplied by the expected change in likelihood of experiencing loss with treatment). Analysis of the economic effectiveness of BAER treatments to protect resource values is complicated by the fact that many BAER treatments are designed to protect resources that have nonmarket characteristics. Identifying appropriate monetary values for these resources presents BAER teams with a number of challenges because of the paucity of information on resource values within the existing literature and management guidelines and the limited time frames allowed for BAER assessments.

The current guidelines for BAER team resource valuation procedures are very general (see US Forest Service 2004, Sect. 2523.1)

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and difficult to implement given the limited time and information available for postfire assessments (Calkin et al. 2007). The final valuation calculations are best described as estimates based on professional judgment (Robichaud et al. 2000). The increased scrutiny of all wildfire-related expenditures requires improvements in benefit/cost (B/C) accounting systems including methods to assess values at risk (VAR).

In this study we show a clear and reproducible valuation procedure that, if adopted, will improve the documentation and defensibility of VAR calculations, particularly regarding valuation of nonmarket resources. The proposed methods were informed by direct field observation, surveys of BAER personnel, a literature review of nonmarket resources typically encountered, and recognition of the challenges of the BAER analysis environment (see Calkin et al. 2007).

Current Valuation Approaches

Under current BAER assessment procedures, identification and quantification of VARs from the effects of wildfires is required, but guidelines to estimate the monetary value of these resources is lacking. BAER teams conduct cost–risk analysis with US Forest Service teams submitting “2500-8” forms and DOI teams develop “emergency stabilization and response” worksheets to document funding requests that establish justification for treatments. US Forest Service BAER teams use benefit cost analysis (BCA) requiring four basic inputs: (1) cost of mitigation treatments, (2) probability of the threat occurring, (3) probability that treatments will be successful at preventing the identified loss, and (4) monetary value change to the resources at risk. The costs of common post-fire treatments have been estimated and are available in the instruction guide for the “cost–risk analysis worksheet” or can be typically obtained from local sources. The probability of the threat occurring and treatment effectiveness can be challenging to develop and may require the use of expert judgment. However, a number of tools such as the Erosion Risk Management Tool (Robichaud et al., 2006) have been developed in recent years to assist BAER teams in assessing the probability of a hydrologic threat occurring and the probability of treatment success. However, there are no tools to guide the calculation of monetary value for resources identified as at risk by US Forest Service BAER teams.

The lack of clear valuation guidelines

for BAER teams lead to variation in specific evaluation procedures from one postwildfire analysis to the next (Calkin et al. 2007). Additionally, a review of past 2500-8 reports by the authors identified that the economic assessment frequently did not properly incorporate the probability of a threat occurring and the effectiveness of treatments in reducing that threat in assessing the benefits of proposed treatments. This results in inconsistent, nonrepeatable analyses subject to local bias. Thorough resource valuation is also hindered by lack of relevant and sufficiently complete resource value data. Finally, the science to support calculation of nonmarket resource values is not sufficiently developed to support general use of developed nonmarket resource values in a monetary framework within the BAER environment.

Currently, US Forest Service and DOI teams use different approaches for cost–risk analysis. US Forest Service teams apply quantitative analysis using BCA, which requires the expected benefits of the treatment (negative outcomes avoided) be assigned a monetary value. If the expected benefits (reduction of value loss to protected resources multiplied by the expected change in likelihood of experiencing loss with treatment), calculated in dollars, exceeds the costs of a proposed treatment, the activity is justified. When the resources to be protected can be easily assigned monetary values such as transportation infrastructure (roads, culverts, and bridges) BCA is relatively straightforward and data requirements are not overly burdensome for BAER teams. With some market resources, such as timber, value change may not be straightforward to calculate because of spatial landscape requirements and allowable cut effects. However, current BAER guidelines restrict emergency treatments to protect life and safety, natural resources (water resources, soil productivity, species habitat, and aquatic and terrestrial native plant species diversity), cultural resources, and investments, and do not allow emergency treatments for the purpose of reducing potential timber or grazing value loss (see US Forest Service 2004, Sect 2523.8.2).

One of the primary challenges faced by BAER teams is that primary data to quantify the resource benefits to nonmarket values of a proposed treatment are typically unavailable. In these instances BAER team members frequently substitute the cost of restoring the system to its preevent condition irrespective of the value associated with the preevent state. For instance, if a high-

intensity postfire rainfall event would result in substantial topsoil loss, the team would assign the value of the resource to be protected as the cost of replacing the lost topsoil— independent of the values that society derived from the preerosion environment. This substitution of cost of restoration for value may be appropriate if the resource was so valuable that the restoration treatment described would be required to take place after the postfire event. However, typically, this level of restoration is unlikely to occur, and, therefore, this substitution may overstate the values to be protected. In some instances nonmarket values are assigned direct monetary values by BAER teams. Because of the limited literature on monetary value change from fire and postfire events to nonmarket resources and the challenges of transferring existing research to new areas, there is reason for concern about the validity of these estimates (Calkin et al. 2007).

Many BAER treatments are designed to protect resources that benefit local residents (e.g., protection of downstream residences from debris torrents) but costs are borne by the general taxpayer. Federal fire management policy and federal emergency management, in general, has typically focused more on economic efficiency than the distribution of benefits and costs (social equity). For instance, the Interagency Strategy for the Implementation of Federal Wildland Management Policy (USDA and USDOI 2003) states, “Setting priorities among protecting human communities and community infrastructure, other property and improvements, and natural and cultural resources will be done based on the values to be protected, human health and safety and the costs of protection.”

Within the current BAER process, treatments are typically identified and developed before BCA, making manipulation of BCA results to justify proposed treatments a potential concern. For instance an individual interviewed during a survey conducted as part of this study commented on the current monetized BCA requirement: “The USFS methodology of cost/benefit analysis was a very much cook the books effort. First, figure out what you want to do then work on the cost/benefit worksheet to reflect that perspective.”

DOI BAER teams apply qualitative analysis ranking the relative importance of the resources to be protected. The qualitative approach is straightforward and simple to implement. However, it does not in-

Table 1. Commonly confused threats and values at risk (VAR) from a recent survey of burned area emergency response personnel.

Threat	VAR
Noxious weeds	Native vegetation Forage for sensitive species
Soil erosion	Life and safety Water quality and secondary consequences
Landslide	Culverts and road system Recreation improvements Road system Road use Aquatic habitat

form decisionmaking on the most important question posed to BAER teams: Is the implementation of a proposed treatment an economically efficient use of limited public funds?

Economic Analyses within the BAER Environment

Economic analysis for BAER teams requires evaluating the risk to resources that may be affected by postfire events. Finney (2005) correctly identifies wildfire risk as the product of the likelihood of an event of a given intensity (threat), times the net value change to the affected resource at the given intensity. By definition, threat is the potential to inflict injury or damage and risk is the probability of a loss occurring. Responses to a recent survey by 214 BAER personnel revealed some commonly confused threats and VARs (Table 1). Directing BAER teams to focus assessment efforts only on VARs potentially threatened by a postfire event instead of all potential postfire threats could help focus BAER field assessment time. For example, an area of high burn severity, as represented by a Burned Area Reflectance Classification image (a common tool used by BAER teams to rapidly assess fire severity using satellite imagery [Hudak et al. 2004]), would not necessarily need to be ground-truthed if no identified VARs are associated with that burned area. Thus, effective cost-risk assessment necessitates a spatial approach, modeling the probability of a given postfire event with the intersection of identified VAR. VARs include both resources within a fire perimeter and downstream resources beyond the fire extent likely to be effected by sedimentation and debris flow.

Where traditional markets for goods and services are clearly identified and de-

finied, values are easily monetized. However, the value of natural amenities and ecosystems are not so easily monetized. Ecosystem functions and the associated outputs of those functions (i.e., goods and services) are often referred to as having nonmarket characteristics; i.e., there is no clear definition of existing markets and no buyers and/or sellers, and, therefore, no equilibrium prices or dollar values assignable to those ecosystem functions. The absence of prices for ecosystem services is likely to cause divergence between social and private benefits and costs. Divergence between social benefits and costs and private benefits and costs can lead to inefficient distribution of resources, and government action is likely to be necessary to correct this market failure (Pigou 1938).

Although there is a substantial body of research into assigning monetary values to forest and rangeland resources, very few of these identify the change in value associated with wildfire or postfire events. Venn and Calkin (2008) summarized the nonmarket literature applicable to wildland fire recognizing that monetary approaches for nonmarket valuation was unlikely to succeed given the variety of resource values threatened by wildfire, the importance of temporal and spatial scales to resource valuation, and limited knowledge of the effects of fire on the resources.

In the absence of site-specific values for nonmarket resources, benefit transfer methods have been suggested. In the case of nonmarket values, benefit transfer is the adaptation of economic information from a specific site and/or resource to another site with similar resources and conditions (Rosenberger and Loomis 2001). Benefit transfer allows a practical way to produce resource valuation estimates when comprehensive research for the site or resource in question is unavailable. Benefit transfer has been most commonly applied to recreation valuation and frequently existing studies must be augmented with additional data, such as demographic and environmental data. Population distribution around the study site has also been found to affect reported benefits (Dwyer et al. 1977) and analysts should be careful to choose appropriate sites for the use of benefit transfer. Both sites should be similar with respect to activities, quality of the activities, and the availability of substitutes (Kirchhoff et al. 1997). Given a number of limitations identified by Rosenberger and Loomis (2001), site similarity requirements, additional data needs,

and the limited number of primary research studies on which to base these monetary values, benefit transfer is of limited functional value in the BAER analysis process.

Alternatively, Montgomery and Pollack (1995) argue that a system of management prices be developed by national or regional managers to be used by local managers in determining efficient management of public lands for biodiversity, a classic nonmarket resource value. The authors base their premise on a body of work conducted in the 1920s and 1930s on market socialism (see, e.g., Lange and Taylor 1938). The premise of the Montgomery and Pollack argument was that local land managers are experts on the productive capability of the lands they manage. However, these managers lacked "global" information about the impacts of their management decisions at the broader geographic scales. Such a system of management prices could inform BAER treatment selection. However, the variety of nonmarket resources encountered within the BAER environment would present significant challenges and require substantial effort to define these management prices, and efforts to reference existing literature would encounter the benefits transfer issues described previously.

Recommended Approach

Results from this study have led us to recommend a hybrid approach for identifying VARs in the BAER environment, suggesting BCA where monetary values are readily available, and using a concept called implied minimum value (IMV) to identify the minimum value of a nonmarket resource loss averted that justifies a proposed treatment. IMV is derived from break-even analysis: What are the minimum benefits necessary such that expected benefits divided by costs are equal to one? It is established by setting expected benefits of the treatment (IMV times the reduced likelihood of loss) divided by expected treatment costs equal to one:

$$\frac{(\text{IMV} * \text{reduced likelihood of loss})}{\text{treatment cost}} = 1. \quad (1)$$

Thus,

$$\text{IMV} = 1 * \frac{\text{treatment cost}}{\text{reduced likelihood of loss}}. \quad (2)$$

The IMV does not necessarily represent the actual dollar value of the resource loss averted;

in fact, the true monetary value need not be defined. BAER teams simply assess whether or not they believe the general range for the true value of the resource protected exceeds the IMV. If the BAER team judges the true value exceeds IMV, the treatment is indicated to be a wise investment of public funds. If they judge the true value is less than IMV, the analysis indicates the treatment is not warranted.

The use of IMV provides an alternative approach to the current US Forest Service requirement of assigning monetary values to nonmarket resources. In addition, IMV does not require that BAER teams acquire any additional data beyond current requirements. It is recommended that teams provide a sufficiently detailed qualitative description of the nonmarket value to be protected so that others, particularly officials charged with authorizing expenditures for treatments, may evaluate the IMV assigned to the resource.

The basis for the IMV approach may be traced to two lines of economic research; break-even analysis and production possibility analysis (PPA). Break-even analysis is frequently used when the benefits (costs) of a proposed activity are difficult to measure but the costs (benefits) are well defined. Break-even analysis simply identifies the point where expected benefits and expected costs are equivalent. Within the area of fire economics research Calkin et al. (2005) used break-even analysis to portray how much bigger two example wildfires would have had to become in the absence of suppression such that the private property values protected equaled the wildfire suppression costs. Additionally, Saveland (1987) examined the monetary tradeoffs of investing in a prescribed fire program up to the point equal to the reduction in future wildfire suppression expenditures using break-even analysis.

PPA uses production possibility frontiers to compare the tradeoffs between competing resource values (Stevens and Montgomery 2002, Montgomery 2003) by mapping all feasible combinations of outputs (desired resource values) possible from a given set of inputs (e.g., a landscape of interest). By selecting a given alternative, the opportunity cost of reaching a specified level of resource output can be explicitly defined in terms of reduction in the competing resource, and when the competing resource is a well-defined market value (frequently forgone timber revenue; see Montgomery

1995, Calkin et al. 2002, and Hummel and Calkin 2005), the implied dollar value of the decision can be identified.

There exists a direct analogy between PPA and BAER treatment options to reduce postfire risk to identified resource values. A BAER team's decision to recommend a mitigation treatment to reduce the likelihood of experiencing a negative outcome to an identified nonmarket resource value implies that the expected change in value of the resource to be protected is at least as valuable as the cost of the treatment. Thus, to calculate the change in value to the resource of experiencing the postfire event or the IMV of implementing the treatment, the cost of the treatment is divided by the reduced likelihood of experiencing the negative outcome compared with the no-treatment option.

When treatments are proposed to reduce the likelihood of losses to both market and nonmarket values within a given treatment area, a mixed BCA-IMV approach may be used. First, the B/C ratio is determined without consideration of the nonmarket values by examining the market resource value change, reduction in the likelihood of loss, and the treatment costs. If the B/C ratio is greater than 1.0, the treatment is justified and the nonmarket values need not be evaluated. If, however, the B/C ratio is less than 1.0, the expected benefits of the market values are used to determine the minimum nonmarket value needed to justify the treatment, i.e., the nonmarket value needed such that the market and nonmarket values set the B/C ratio equal to 1.0:

$$\frac{(\text{market value} + \text{IMV}) \times \text{reduced likelihood of loss}}{\text{treatment cost}} = 1.0. \quad (3)$$

Thus,

$$\text{IMV} = \frac{\text{treatment cost} - (\text{market value} \times \text{reduced likelihood of loss})}{\text{reduced likelihood of loss}}. \quad (4)$$

Here, we provide two hypothetical examples of the use of IMV that are loosely based on BAER assessments for the 2006 Gash Creek fire on the Bitterroot National Forest in Western Montana. In the first example, a seeding treatment costing \$5,000 was proposed to protect native bitterroot flowers (*Lewisia rediviva*) from nonnative species invasion. The bitterroot, the Montana state flower, is a species with heritage

value to native people and is uncommon in burned areas and is becoming rare throughout the region. Consider that the likelihood of local extirpation of the bitterroot because nonnative invasion on this area is estimated at 50% and the proposed seeding treatment is estimated to reduce the likelihood of local extirpation to 20%. Therefore, if the proposed seeding treatment is implemented, the IMV of protecting the bitterroots from local extirpation is \$16,667 ($\$5,000 / [0.50 - 0.20]$). The decision on whether the treatment is justified is then a local management decision. Does the team judge that the presence of bitterroots in this location is worth at least \$16,667? If so, the treatment is justified, if not, the treatment should not occur.

In example 2, we evaluate both market and nonmarket resource values using a hybrid approach including BCA and IMV. For this example the VARs include five culverts and a portion of road surface that would need to be replaced if an identified postfire erosion event were to occur at a total replacement cost of \$60,000. The team has determined that because of access requirements road closure is not an option. If this event occurs there would also be loss of bull trout (*Salvelinus confluentus*) spawning habitat for approximately 5 years. The bull trout is listed as a threatened species under the Endangered Species Act (Burton 2005). The proposed treatment is to upgrade the existing culverts at a total cost of \$40,000. Consider that the likelihood of culvert and road failure under the no-treatment alternative is estimated at 50%. If the culverts are upgraded, the likelihood of loss is reduced to 10%. Evaluating the market values only results in a B/C ratio of 0.6; thus, the treatment is not justified by market VARs alone. The difference between the treatment cost and the expected market benefits is then used to compute IMV for the nonmarket value using Equation 4, resulting in an IMV for the nonmarket resource of \$40,000. If the value of maintaining this spawning habitat is at least \$40,000, then the treatment is justified.

The IMV is based on the relative change in probability of loss not the absolute probability of loss. Therefore, the IMV of reducing the likelihood of habitat loss from 60 to 30% is equivalent to reducing the likelihood from 30 to 0%. In the case of unique and highly important nonmarket VARs, the concept of acceptable risk may need to be evaluated, and treatment programs with higher IMV but lower posttreatment threat

may be preferred to programs with a lower IMV but a higher posttreatment threat. For example, an isolated section of critical spawning habitat for an identified threatened and endangered species in which their loss could result in species extirpation may suggest a very low level of acceptable risk. Therefore, a treatment program that reduces the likelihood of loss from the non-treatment level of 60–10% at a treatment cost of \$250,000 (resulting in an IMV of \$500,000) may be preferred to a treatment that reduces likelihood of loss to only 30% at a treatment cost of only \$30,000 (resulting in an IMV of \$100,000). The more expensive treatment (and greater IMV) is preferred because the value of the habitat is deemed to exceed \$500,000 and a 30% likelihood of loss is considered unacceptable.

The IMV is sensitive to the reduction in the probability of loss due to treatment and in many field instances these estimates will have considerable uncertainty due to a lack of data or appropriate models to quantify these probabilities. In these instances, sensitivity analysis should be conducted on the relevant parameters. Consider the first example provided regarding treatments designed to protect the sensitive bitterroot. Under the current assessment the IMV associated with reducing the likelihood of loss from 50 to 20% was \$16,667. However, if in fact the likelihood of extirpation without treatment was 60% and the treatment would reduce this to 10%, the IMV would be \$10,000. However, if without treatment the likelihood of extirpation was 40% and treatment only reduced it to 30% the IMV would be \$50,000. Thus, the calculation of IMV is highly sensitive to these probability estimates, particularly when treatments alter the likelihood of experiencing the loss only a small amount. Although the calculation of the IMV is sensitive to parameters that may be challenging to accurately calculate, this sensitivity reflects the reality of investment under uncertainty and should focus teams on identifying the relative effectiveness of treatments in reducing loss to resource values.

Discussion and Conclusions

Economic valuation within the BAER environment presents unique challenges. Teams are formed immediately after a large wildland fire event and are expected to complete the analysis and develop proposed treatments within 7–10 days of convening. The majority of team members represent the

disciplines of hydrology and soil science, and it is extremely rare that team members have formal training in economics (Calkin et al. 2006). However, BAER teams are required to conduct BCA and develop monetary estimates for nonmarket VARs to postfire events. The literature on nonmarket valuation is inadequate for field use and extensive challenges exist in transferring monetary value estimates to field situations. Given these challenges it is not surprising that the current valuation process is viewed as a required process to be overcome and not a meaningful analysis to improve field decisions on the appropriateness of postfire treatments.

We propose a modification to the current BCA framework for analysis of nonmarket VARs. This framework, called IMV uses the cost of proposed treatments and the likelihood that the treatment will reduce resource loss to define the minimum value a nonmarket resource must have to justify the proposed treatment. This process is derived from economics research using break-even analysis to determine a minimum value threshold that must be met when the benefits from a proposed activity are difficult to measure. IMV is also related to research that explores the use of production frontiers to examine resource tradeoffs and determine implied values of management decisions. IMV retains local management control of treatment decisionmaking. Unlike BCA the outcome of an IMV analysis does not suggest whether a treatment should occur or not; it presents a minimum amount that the resource value must exceed for BAER teams to recommend the treatment. In addition, IMV removes the requirement that nonmarket resources be directly assigned monetary values—a requirement that can not be justified by data and methods currently available to BAER teams. Finally, the IMV approach does not require that field teams collect any additional data beyond what is currently obtained. In fact, it reduces data requirements.

IMV represents a new conceptual approach for nonmarket valuation to BAER teams and will require training and familiarity for users to become comfortable with the concept. However, it is not very different from the current decisions that managers are experienced in making. Public land managers are very familiar with making investment decisions with public funds to improve or protect nonmarket values. Although determining if the value change to the nonmarket resource value exceeds the IMV is subjective,

this approach provides a consistent method to incorporate the uncertainty that treatments change the potential outcome to resources at risk and allows the subjective determination to be reviewed by authorizing officials who are designated to approve treatment expenditures. In addition, the usefulness of the IMV approach may well extend beyond the postfire environment. As managers become more familiar with IMV and a body of IMV estimates become established, management prices for nonmarket resource values (as suggested by Montgomery and Pollack 1995) could eventually be developed by reviewing past decisions.

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