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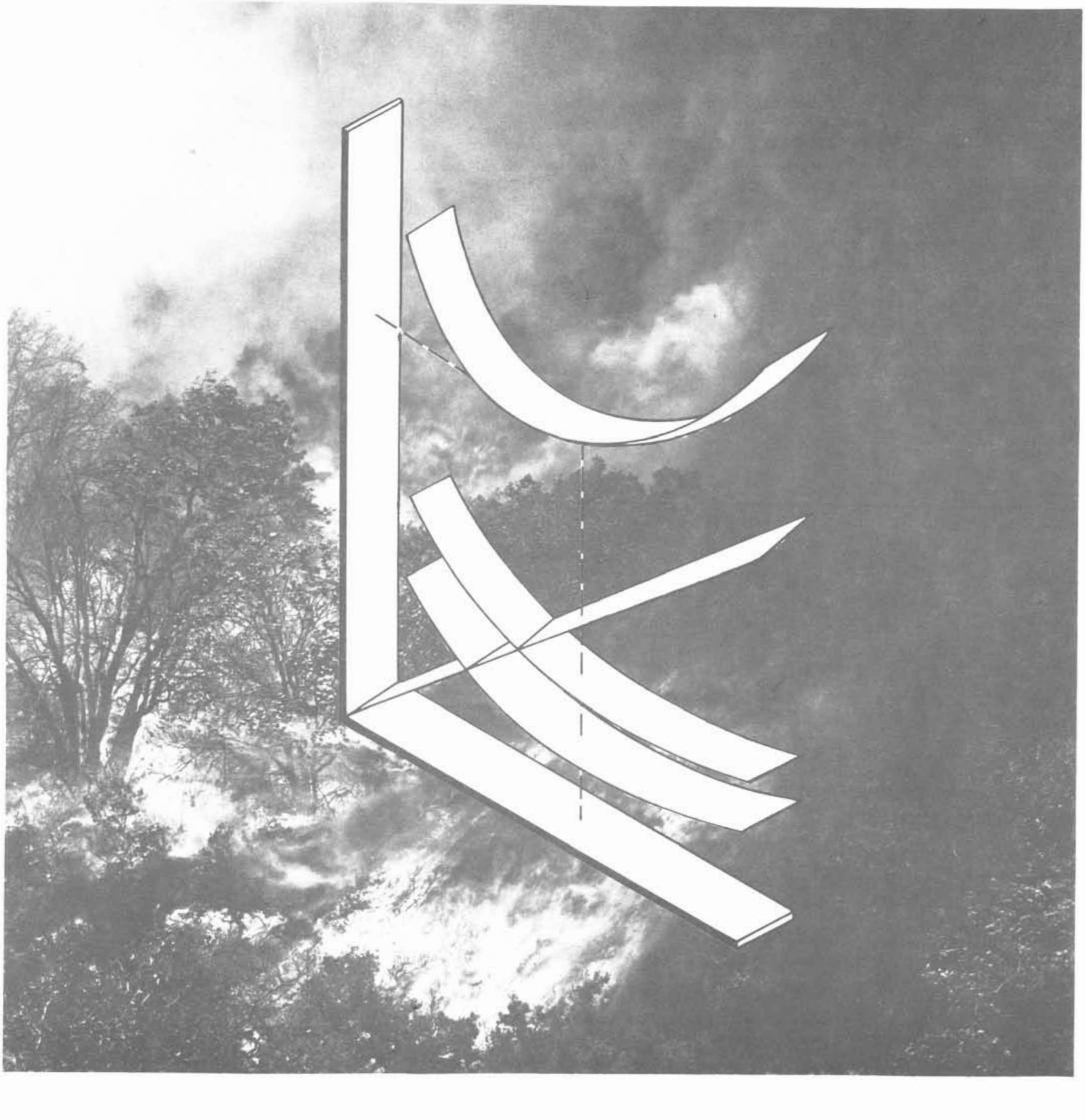
Resource Values in Analyzing Fire Management Programs for Economic Efficiency

Irene A. Althaus Thomas J. Mills



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IN BRIEF . . .

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The same basic valuation principles which apply to an economic efficiency analysis of any natural resource program also apply to public fire management programs. The fire analysis problem, however, adds some unique requirements for both the structure of the analysis and the application of the valuation principles. The appropriate economic selection criterion among fire program alternatives is the minimization of the program cost plus the net value change in resource outputs (C + NVC). The C + NVC criterion recognizes the beneficial as well as the detrimental effects of fire resources.

Several factors must be considered when determining the scope of the fire effects and commensurate resource values needed in the fire program analysis. The analysis should consider the effects of fire on resource output at the fire site and the direct physical effects away from the site. All resource outputs that can be valued in dollars should be included in the net value change calculation; resource output that cannot be readily measured in dollars should not be forced into the economic analysis. Fire effects on rare and endangered species are examples of this latter class of outputs. Intended resource use plays an important role in determining fire effects. A resource loss takes place only if the resource output would have occurred in the absence of the fire.

The substitution of unburned for burned resources within the planning unit should not, with a few exceptions, be included in the fire effects calculations. Substitution is more a reflection of institutional setting than of inherent site and program productivity. The fire management efficiency analysis should reflect inherent productivity as clearly as possible.

Rehabilitation impacts on resource outputs over time must be included in the fire management analysis even though the rehabilitation decision is separable from the fire program decision. The rehabilitation options should be screened against an economic efficiency criterion so as to ensure that high-cost, but inefficient activities do not bias the fire management program selection.

The valuation procedure used in fire program economic analyses must be free of market distortions and operate where there is a lack of a commercial market. A single valuation procedure must be applicable to all resources to avoid bias. The value must reflect the full economic value to society and not just that portion which can be captured in commercial markets or by individuals. Willingness-to-pay values meet these criteria.

The per unit value should be measured across the margin of fire-induced output change. The marginal willingness-to-pay, rather than the average, is the correct value measure for a marginal analysis of fire management program alternatives. This difference between the marginal and average value is important since the marginal value is always less than the average value. The amount of difference is a function of demand elasticity and the increment of output change induced by the fires.

Demand elasticity and the magnitude of the resource output change also have an impact on the practical derivation of marginal willingness-to-pay value estimates. If *either* the demand function is highly elastic or the output change is small, the initial willingness-to-pay per unit value is a reliable estimate of the marginal willingness-to-pay. This initial willingness-to-pay can be approximated with the initial market price for resources traded in competitive markets.

Past studies indicate that timber and improvement values have the greatest net value changes, and that errors in their per unit value estimates have the greatest impact on economic efficiency results. Initial efforts to refine value estimates for fire analyses should, therefore, be concentrated on these two resource categories. The resource values for the other resource categories that were compiled from past studies for use in the 1978 Resources Planning Act analyses should be used at this time. All value estimates should be subjected to sensitivity analyses in a prototype fire economic evaluation model. Without such analysis, it is not possible to determine how accurate the value estimates must be.

The soaring cost of fire presuppression and suppression has intensified demands for identifying the "best" fire management practices. These demands stem from actions by the Congress (U.S. Senate 1978), U.S. Office of Management and Budget (U.S. Dep. Agric., Forest Serv. 1977), and Forest Service, U.S. Department of Agriculture. In 1978, the Forest Service announced a change in its fire management policy, requiring that fire management programs be cost-effective and compatible with land management activities.

To meet these objectives, fire management programs must be economically efficient. Analyses of programs to determine efficiency must consider resource values on as accurate and realistic terms as possible. Until recently, proxies for resource values, such as "acres burned," were used. Another practice has been to use the values for Potential Damage Class, for which it is assumed that all fires burned at their highest intensities (U.S. Dep. Agric., Forest Serv. 1963). For a full economic evaluation of program alternatives, more accurate estimates of resource values are needed than either of these approximations can provide.

Fire management programs influence the flow of resource outputs from the forest, whether they are products or amenities, as well as the per unit value of these resources. Values should be expressed in monetary terms because dollars serve as the common denominator by which the benefits and costs of fire management programs can be aggregated and compared. Much of the information needed for estimating values can be drawn from the same concepts and approaches used in evaluating resource output from other public programs.

This report reviews the economic concepts basic to resource valuation in analyzing public programs, and identifies the specific considerations of values appropriate to fire management programs. It specifies the categories of resource output most useful in analyzing programs for economic efficiency. The valuation approach suggested is applicable to broad resolution analyses of fire management program economic efficiency for regional or major subregional planning decisions.

CRITERIA OF ECONOMIC EFFICIENCY

An accurate criterion of economic efficiency for fire management programs is the minimization of cost plus loss, or more fully, cost plus net value change (C + NVC) (Mills 1980). This criterion offers the advantage of compatibility with the expression of both resource losses and beneficial effects that fires, and fire management actions, have on resource outputs.

The problem that hindered past efforts of economic analysis was the lack of an analytical model that considers the occurrence, behavior, and effects of fire, the effectiveness and costs of fire management, and the value of resources. Without such a model, the C + NVC functional relationships could not be derived. The appropriate model should evaluate fire management expenditures, like any other land management activity, on the basis of changes in resource values that a program generates.

The C + NVC function is derived by adding presuppression cost to the cost of fire suppression and the value of the change in resource outputs that result from the fires. The most efficient level of fire program input is the point where the summation is minimized (PL_1) in the hypothetical relationships (*fig. 1*). The net value change (NVC) sums up the change in the quantity of resource outputs that result from the fires times the per unit value of output:

$$NVC = \sum_{i=1}^{n} [(Q_i - Q_i') V_i]$$

in which

Q = output level without the fire
Q' = output level with the fire
V = per unit value
i = resource category
n = number of resource categories.

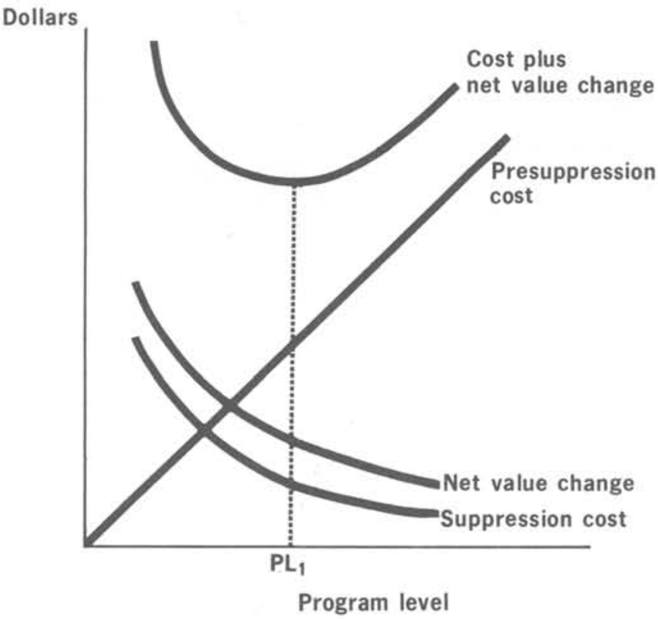

Figure 1—Minimization of cost plus net value change identifies the most efficient fire management program level.

This derivation of NVC differs substantially from that typically found in public program efficiency analyses. The typical comparison in such analyses is with the *program* v. without the *program*. The with v. without program comparison is inappropriate in fire program analyses because it is not possible to determine how large fires would become in the complete absence of a fire management program.

A program level that results in no fires—even if this were technologically feasible—is not necessarily the most efficient. Resource outputs in the absence of fire are simply used in the NVC calculation as a common benchmark for measurements. These measurements serve in the NVC calculation similar to the way they entered the "loss" term in past calculations of cost-plus-loss.

Comparing output levels with and without *fire*, rather than the *programs*, means that the C + NVC criterion is a modified marginal criterion. Consequently, no efficiency conclusions can be drawn from a single C + NVC calculation. Instead, the C + NVC of sequential fire management program levels must be compared with each other until a minimum is located.

No single fire management analysis model is appropriate for all fire management program questions. A number of spatial and temporal resolutions are relevant. The resolution levels vary from broad questions about resource program opportunities to site- and time-specific analysis of individual projects, such as escaped fires. The resolution of the resource value estimates must be tempered by the resolution of the analysis within which they will be used.

CHANGES IN RESOURCE VALUES

Resource values discussed here are restricted to changes in resource output at the site of the fire, such as a decrease in timber harvest because of trees killed by fire, and to those away from the site that are a direct result of the fire, such as a decline in usable waterflow downstream from the fire.

Three broad types of output or effects are excluded: (1) secondary effects, such as the effect on local income or employment; (2) substitution effects, such as harvesting unburned timber in place of burned timber; and (3) resource outputs that cannot be assigned dollar values, such as rare and endangered plants and animals. This is not to say these excluded effects are unimportant. They are simply beyond the scope of this report, and it is generally not appropriate to include them in an economic efficiency analysis.

The exclusion of secondary effects originates in part from the difficulty of tracing the multiplier effects throughout the market, and identifying the final net secondary effects. Although secondary effects can have significant local implications, the question is whether they have a net regional impact (Knetsch 1969). The general conclusion for most resources affected by fires is that they do not have a net regional impact.

Exclusion of Substitutes

Whether unburned resources should be substituted for burned resources is an important question that arises in any evaluation of a fire management program. In timber management programs, a similar question is whether the allowable cut effect should be used to measure silvicultural program effects or whether the benefit of cutting should be measured only by the productivity of the sites that were treated.

The evaluation of fire management program alternatives should, in our judgment, as clearly as possible reflect only inherent site productivity. Most of the important substitutions which occur in an analysis are the result of site productivity intermeshed with institutionalized decision rules, such as pursuing a nondeclining even-flow of timber yields. We are, therefore, proposing that substitution in general be *excluded* from the fire management analysis at the regional level. Institutional rules and settings should stem from broad resolution planning rather than precede it.

We recognize that the measurement of fire effects, and therefore NVC, in the absence of substitution does not reflect the actual cash flow that comes from an area encumbered by its institutional setting. Such measurement does, however, more accurately reflect the inherent productivity of the site and the fire management program. At the regional level, the goal should be to determine this inherent productivity and allocate funds according to it. In an economic sense, the unburned resources could have been utilized anyway, even if the fire had not burned. The fire management and the postfire substitution decisions are technologically separable, and they should be analyzed independently.

Postfire substitutions may be separated into two categories. The first category requires a manager to decide about using resources that would not have been used had there not been a fire. A decision to sell timber on a National Forest that would not have been offered for sale in the absence of the fire is an example. This form of substitution will not be considered in this discussion. We recognize that ignoring this management-induced substitution produces a higher estimate of fire-induced losses and fire-induced benefits than if it were included.

The second category consists of those that result from decisions made by resource users. The movement of recreationists to an alternative site after one has burned is an example. Substitution which results from users' decisions can take place only if unused resource capacity is available, for example, if adjacent campgrounds are not filled to capacity. If unused camping capacity exists in a nearby area, the value lost due to the burning of a campground equals the additional cost of transportation to another site and perhaps a congestion-related decrease in value per recreation visit. Given the usual procedures for estimating recreation usage and value, it is questionable whether this form of substitution could be excluded from an estimate of the fire effects on recreational usage. The user-induced substitution should therefore be included in the fire program analysis.

The proposal to exclude all substitution, except that resulting from user decisions in the recreation categories, is consistent with the methods used for estimating fire effects by other investigators (Schweitzer and others 1981, U.S. Dep. Agric., Forest Serv. 1980). Preliminary results available from previous analyses indicate that recreation-related effects have a minor impact on the fire management analysis results. In net then, essentially all important substitution has been excluded.

Intended Use of Resources

The intended use of a resource helps determine the scope of the fire effects and the values needed in the analysis. Only resource outputs actually affected by fire or fire management programs should be included in the NVC calculation. For example, commercial fishing losses should not be included when fire-induced erosion affects fish spawning areas if no commercial fishing occurs anyway, with or without the fire. Similarly, a fire in a wilderness area that kills trees does not affect the output of timber because no timber would have been harvested there in the absence of the fire. But the wilderness fire could affect the recreation output of the area if recreational use is related to the vegetative cover.

The intended resource use also affects the timing of the fire effects for valuation purposes. For example, if fire burns an immature timber stand, the effect upon resource outputs is the future timber harvest foregone rather than an immediate change in output. That future harvest is the commodity which must be properly valued, using estimates of its future per unit value. The future net value change must then be discounted to the present for inclusion in the NVC calculation.

Postfire rehabilitation decisions, such as reseeding grass to reduce erosion can have a major impact on the efficiency of the fire program. Unlike the resource substitution, however, the results of the rehabilitation decision affect future resource outputs on the fire site. The rehabilitation impacts must therefore be included in the fire management analysis. For example, if reseeding reduces the effects of erosion from 5 to 2 years, the cost of reseeding and 2 years' erosion effect should be included in the fire program analysis.

The rehabilitation decision should be kept distinct from the decision on the most efficient level of the fire management program. Extensive and high cost rehabilitation activities can be decisive in determining which fire management program level is most efficient. The high cost of rehabilitation activities can raise the most economically efficient fire program level, even if the net resource damage was not materially reduced by the rehabilitation. To avoid this potential bias, the rehabilitation alternatives should also be evaluated by economic efficiency criteria before inclusion in the fire management analysis.

RESOURCE CATEGORIES AND VALUATION

To further define the resource value needs for a fire management analysis, we developed a list of resource categories, elements of the resources, units for measuring use, and indication of marketability (*table 1*). Each resource output is measured in units which reflect human use of the resource and units which can be expressed in dollars. Wilderness and wildlife outputs, for example, are both measured in recreation visitor-days instead of esthetic appreciation and wildlife habitat, respectively.

An improvement category is also included (*table 1*). Homes, administrative structures, and a host of other improvements, such as fences and roads, are affected by fire or by the erosion and flooding which is related to the fire. Since these effects on improvements occur on the fire site or are a direct offsite effect, they should be included in the net value change calculation.

All direct effects which cannot be readily measured in dollars, such as the effect of fire on endangered plant or animal species, the option value of a wilderness area to nonusers, or the loss of human life are excluded. These unvalued effects should be considered in the fire program decision, however. The relative weights between the dollar valued and nondollar valued outputs should be supplied by the decisionmaker. The economic efficiency analysis is, therefore, only a partial analysis rather than a whole-decision model.

The resource categories include a mixture of marketed and nonmarketed outputs (*table 1*). Some are traded in commercial markets while others are public goods which are not assigned monetary values in commercial markets. The valuation problem is further complicated because some markets operate imperfectly.

The resources can be categorized into four groups on the basis of the type of transaction in which they are typically involved:

Marketed resources:

- Values are set by commercial market transactions in relatively competitive markets, e.g., timber prices.
- Administratively determined fees are charged which are related to, but do not represent full value to users, e.g., grazing fees. Although a semblance of a commercial market exists, significant market distortions are present.

Nonmarketed resources:

- Administratively determined fees are based on administrative costs rather than any proxy commercial market value, e.g., fees for developed recreation.
- No commercial market exists nor are fees charged, e.g., wilderness recreation.

The resource valuation process must adjust for market distortions as well as the lack of a formal market. The process must also estimate the full economic value of the resource outputs to society. Prices and fees are not always an adequate basis for value determination. If the dollar value from existing transactions were used exclusively, the analysis would be biased against resource outputs that are undervalued by existing fees, such as grazing, and against resources not traded in commercial markets, such as wilderness recreation.

A value bias would also be introduced if different valuation measurement concepts were applied to the different resource categories. For example, if estimates of market price were used, the net value change would be calculated by multiplying the change in output times the price existing before the loss. The demand function elasticity would not influence the resultant estimate of net value change.

If, on the other hand, willingness-to-pay estimates were used, where willingness-to-pay includes consumer surplus as well as market revenue, both the per unit and total value loss estimates are directly influenced by the elasticity of the demand function at the quantity level where output is affected. The willingness-to-pay estimate of net value is either higher or lower than the estimate derived by using market

Table 1—*Fire sensitive resources and primary form of transaction*

Resource	Elements	Unit	Transaction: Market	Transaction: Nonmarket
Commercial timber	Sawtimber and pulpwood (classified by species, age, and other characteristics which influence value)	Thousand board feet, cubic feet	X	
Commercial range	Livestock grazing	Animal unit months[1]	X	
Recreation	Developed—private	Recreation visitor-days[2]	X	
	Developed—public	Recreation visitor-days		X
	Dispersed	Recreation visitor-days		X
	Wilderness	Recreation visitor-days		X
Water	Water quality reduction	Cubic feet—sediment removal	X[4]	
	Water quantity	Acre feet	X	
Wildlife	Nonconsumptive[3]	Recreation visitor-days		X
	Consumptive:			
	Hunting:	Recreationvisitor-days		X
	Fishing:			
	Sport	Recreation visitor-days		X
	Commercial	Pounds	X	
Capital improvements	Federal, management	Unit	X[4]	
	Federal, administrative	Unit	X[4]	
	Private	Unit	X[4]	
	Other	Unit	X[4]	

[1]AUM = amount of feed or forage required by one mature (1000-lb) cow or equivalent for 1 month.
[2]RVD = one visitor-day equals 12 hours (1 person for 12 h, or 12 people for 1 h, or any combination thereof).
[3]Example is bird watching.
[4]Restoration costs including costs of repair, replacement, or rehabilitation serve as substitutions for value.

prices, depending on whether the fire produces an increase or decrease in resource output, respectively. The magnitude of difference between market price and the willingness-to-pay unit values is a function of the demand elasticity and magnitude of the fire-induced change in resource outputs.

To overcome such differences among valuation methods, the values for all resource categories should be assigned in the same way. This consistency should exist not only among resources but also among fire management program alternatives being evaluated.

The resource values should also represent the value to society rather than to any individual. Since the purpose of a fire program efficiency analysis is to provide information relevant to public program decisionmaking, a societal perspective is appropriate. Societal values in some instances exceed revenues collected and returns captured in a commercial market.

The fire effects should be recorded for both beneficial and detrimental consequences of fire. For example, grazing output can be higher 1 year after a moderate intensity fire than it would be in the absence of the fire. Major quality effects which actually reflect a change in the resource category should also be represented. The market in which fire-killed timber is bought and sold, for example, is probably really a different market in an economic sense than the one in which unburned timber is priced. Different values may therefore be appropriate for the two different resource categories, salvage and green stumpage.

It is also important that the resource for which the value is derived is the resource which is really affected by the program being evaluated.[1] Fire, for example, affects standing timber—not lumber. Stumpage is the resource which must be valued then—not lumber that contains a value-added due to transportation and processing. This point is especially important for resources not traded in commercial markets.

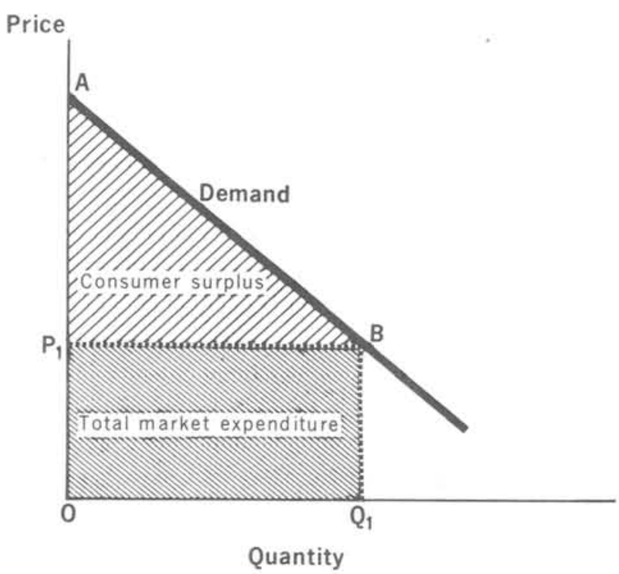

Figure 2—Total willingness-to-pay is composed of total market expenditures plus consumer surplus.

In short, a single valuation measurement must be chosen and applied uniformly to all resource categories. The values must reflect a societal view. The valuation concept must lend itself to application to both marketed and nonmarketed resources. And finally, the value measurement should be made for the resource actually affected by the program being evaluated to be sure that inappropriate value-added is not contained in the value estimate.

WILLINGNESS-TO-PAY VALUATION

The willingness-to-pay concept meets these valuation criteria. It goes beyond actual dollar transactions and represents the total economic value to society. Value measurements are based on the dollar amount that *users* would be *willing to pay* to secure the benefits if confronted with the choice of consuming the benefit or going without it.

Technically, losses should be measured by the minimum amount of compensation individuals would be willing to accept in exchange for having the losses imposed upon them. This is termed "willingness-to-sell." Under competitive conditions, or where there is a price effect but the income impact is negligible, willingness-to-sell equals willingness-to-pay. However, the amount a consumer must be paid in order to voluntarily forego the benefit can differ greatly from a consumer's willingness-to-pay for a benefit due to income limitation (Mishan 1976). Resource output changes can take the form of either a loss or a gain, depending upon the effects of the fire and the fire management program characteristics. We use willingness-to-pay measures in this report for simplicity.

Willingness-to-pay values for nonmarket outputs are directly comparable with values developed for resources traded in a commercial market. The willingness-to-pay for fire-induced output changes exceeds the revenue that can be captured in a commercial market whenever (1) the goods or services are rationed, formally or informally, by any means other than price; or (2) the output represents more than a marginal increment in the total supply of the goods or service; and (3) when perfect price discrimination is not employed in the distribution of the output (Marglin 1967).

[1]Convery, Frank F. Development of common measures of value for multiple forest outputs. 1974. Unpublished draft supplied to authors by Frank F. Convery.

Theoretical Basis

Total willingness-to-pay equals the maximum revenue that a perfect price discriminator could collect if the output were sold one unit at a time to the highest bidder (area $OABQ_1$ in *fig. 2*). The area under the demand curve can be separated into two parts: total market expenditures (area OP_1BQ_1, *fig. 2*) and the gap between the willingness-to-pay and the total market expenditures (area P_1AB, *fig. 2*). This second part is the consumer surplus or unpaid-for increment. It is a benefit received but not paid for by the consumer when goods are sold at a single price. Consumers pay only the total market expenditures, not what they would be willing to pay.

This same value measurement can be applied to market and nonmarket outputs. When existing price information misrepresents value due to market distortions or a lack of market structure, special value assessment techniques can be used to determine user's incremental willingness-to-pay for varying quantities of the outputs. The special techniques are used to derive portions of the demand curves for the various resources.

Consumer surveys and bidding games can be used to derive the relevant demand function segment for recreation resources. Another approach is to estimate the marginal-value-product of an added increment of resource input into the production of another good. This technique is applicable to outputs such as grazing and water which are inputs to meat and crop production respectively (O'Connell 1972). Market prices of close substitutes may also be used if the markets in which substitutes are traded are competitive. The rental rate of commercial pasture and use rates in commercial campgrounds, for example, provide market price estimates for grazing and public recreation once comparability adjustments have been made. Using the above techniques, the per unit value can be calculated for the quantity supplied. This value can then be treated like a price derived in a commercial market.

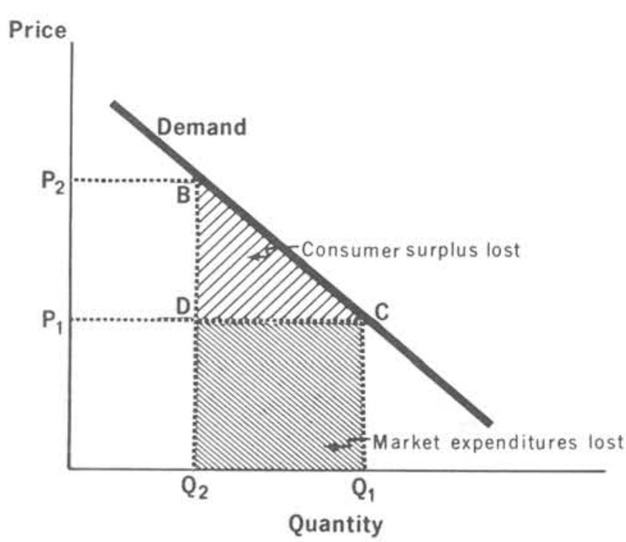

Figure 3—Marginal willingness-to-pay is measured only over the range in output change induced by the program.

Marginal Values and Output Change

Depicted graphically, total willingness-to-pay is the entire area under the demand curve up to the quantity level currently being consumed. The relevant willingness-to-pay value for fire program evaluations, however, is not the total willingness-to-pay. It is only the willingness-to-pay over the margin of output change induced by the fire program. The entire demand curve is not needed for this marginal calculation. The NVC for the fire program is calculated by multiplying the change in output times the per unit value at that margin of change. The distinction between the marginal and average willingness-to-pay is an important one. The average is always greater than the marginal value, and substantially so if the output quantity is large and the demand is highly inelastic.

The net value change to society of a loss in resource output from Q_1 to Q_2 in *figure 3* is the area defined by Q_2BCQ_1 (Dohan 1977). This loss equals the foregone market expenditures plus the consumer surplus lost due to the quantity reduction. The larger the marginal output change, the less accurately the initial equilibrium price (P_1) approximates per unit willingness-to-pay at the margin.

If the demand curve is linear, the per unit willingness-to-pay value across the change margin is equal to the average of the prefire price (P_1) and the postfire equilibrium price (P_2). This marginal per unit value multiplied by the change in output (Q_1-Q_2) yields the net value of the resource output change which results from a given fire management program option.

Market and Demand Curve

The marginal willingness-to-pay value can be estimated by the prefire per unit price if either one of two market-related conditions are met: (1) the fire program-induced change in output is smaller than the total quantity available in the market served, or (2) the demand curve is so elastic that the price change is negligible (*figs. 4, 5*). These conditions involve the magnitude of the fire program-induced quantity change and the demand elasticity.

The willingness-to-pay values are easier to estimate under either of these two conditions because observed market prices are a good approximation of the marginal value for those resources traded in a reasonably competitive commercial market. A demand function does not need to be constructed, even that portion of the demand function over the range of output change induced by the fire.

The effect of fire on timber generally meets the condition of small quantity change. Its effects on the quantity of timber actually supplied in a regional or subregional timber market is usually small and will lead to no significant price effect. A drop in quality may force prices downward, and therefore, salvaged timber and green timber may need to be priced separately. The only substantial effect on timber prices may result from an interaction between the green and salvage timber markets when large fires occur.

If the resource is not traded in a commercial market, the segment of the demand curve over the margin of output change must be derived before the prefire value can be estimated. If either condition concerning marginal change and demand elasticity is met, though, the initial value can still be used for all fire program alternatives. Grazing and some forms of recreation meet these conditions.

The spatial nature of the market for water and some forms of recreation, and accompanying high transportation costs, sometimes lead to a localized market. As a result, the fire-induced quantity change may be large relative to the total quantity in that market. Large, multiple fires could also violate the condition of small quantity change for all resources, including timber, even if their markets are not localized. An exceptionally large fire, for example, may place so much salvaged timber on the market that green timber prices are depressed for a short period.

If the output change is large and demand is highly inelastic, such as the hypothetical curve in *figure 3,* the per unit willingness-to-pay value estimate must include changes in consumer surplus between the two output levels. These conditions are most likely encountered with resources traded in small markets and for scarce resources where the output quantity is low relative to the fire impact on output. Some recreation resources fall in this class; in some areas, so does water.

The relevant value is still the one across the margin of output change induced by the fire, however, and not the average willingness-to-pay under the entire demand curve. The initial market price would represent an underestimate of the willingness-to-pay across the output change margin if a fire had reduced resource outputs. Conversely, it would be an overestimate if a fire had increased outputs. Even in this case, however, willingness-to-pay can be estimated from estimates of initial per unit value and demand elasticity. An entire demand function is not needed, or even a portion of the demand function, if a prefire value estimate is available.

In summary, under certain conditions, it is not necessary to construct an entire demand curve in order to estimate the marginal willingness-to-pay values. Under other conditions, an initial or prefire value in conjunction with an estimate of demand elasticity is sufficient information from which the appropriate marginal willingness-to-pay can be derived. The portion of the demand curve over the relevant segment of resource output can be provided from that initial data. Construction of the entire demand function is seldom necessary.

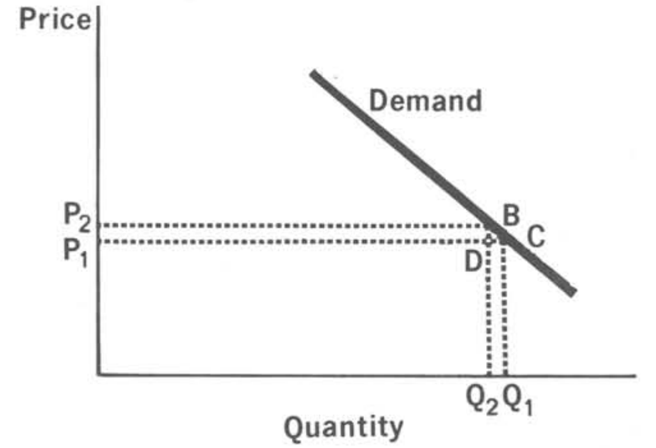

Figure 4—An inelastic demand and small quantity change lead to a small change in price.

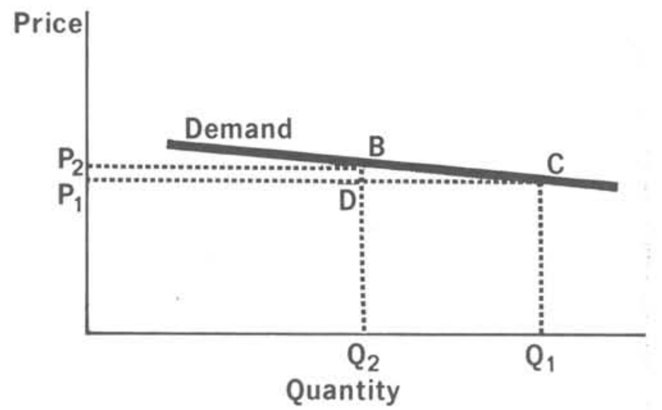

Figure 5—An elastic demand and a large quantity change lead to a small change in price.

ESTIMATING VALUES FOR FIRE ANALYSES

Given this theoretical basis, a practical approach to value estimation for fire management analyses must be established. Historical market information is readily available for timber and improvements. If it is assumed that the timber market is relatively competitive and the timber loss does not significantly affect price, actual market prices can be used as an approximation of the per unit willingness-to-pay across the change margin. Market price or the cost of reconstruction and repair can serve as a substitute for the value loss of improvements. Value estimates for the timber and improvement resources can therefore be drawn directly from historical records of transactions.

We know of only a few studies that provide value estimates for resources, such as water and recreation, which are not traded in commercial markets or traded under imperfect market conditions. The value model specifications in those studies were not uniform and the resulting value estimates are highly variable. The site-specific nature of most past value studies makes extrapolation to other locations difficult. Because resource valuation studies are often very costly to undertake, however, and because there is controversy about the form and soundness of the measurement techniques (Bowes and Dwyer 1980, Johnson 1980, King and Davis 1980), past studies should be used as much as possible.

The resource value estimates from past resource value study results were incorporated into the values used by the Forest Service in the development of the Resources Planning Act (RPA) program (U.S. Dep. Agric., Forest Serv. 1980). The RPA values are average willingness-to-pay estimates derived by adjusting the results of past studies to a common base.

The RPA values, expressed in first-quarter-1978 dollars, contain most of the resource categories required in regional-level fire management analysis (*table 1*). They do not include separate prices for salvaged timber or for timber species strata beyond the hardwood-softwood division. Nor do they include the prices for improvements which may be lost as a result of fire. These added categories were not required for the national-level evaluation of RPA program alternatives.

The RPA value estimates evolved through several steps of refinement before their final use in the national-level program development exercise. They have also been refined since that time to provide guidance for the land management planning process underway on individual National forests (*table 2*). It is likely they will be refined in the future.

While we readily agree that currently available resource value estimates pose problems, significant research on their

Table 2—*Resources Planning Act values, in dollars per unit as of first quarter 1978, by resource element and region*[1]

Element and output description[2]	Output measure[2]	Forest Service Administrative Region								
		1	2	3	4	5	6	8	9	10
		Dollars								
Timber										
Timber hardwood sawtimber	MBF	1.13	1.64	6.32	2.80	17.15	22.54	37.51	49.18	1.01
Timber softwood sawtimber	MBF	78.51	34.25	76.46	48.69	127.66	173.23	118.15	38.17	32.72
Timber hardwood roundwood	MCF	—	45.13	49.09	10.73	52.56	101.30	21.82	32.51	5.56
Timber softwood roundwood	MCF	31.57	13.83	33.90	58.02	40.10	208.78	115.69	87.62	3.67
Water										
Water yield	AF	7.50	5.00	5.00	5.00	2.60	1.50	1.50	1.00	0.50
Net sediment reduction (avg.)	AF	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Recreation										
Dev. recreation use—public	RVD	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Dev. recreation use—private	RVD	3.00	3.75	3.00	3.50	3.50	3.50	2.50	2.00	3.00
Dispersed recreation use	RVD	3.00	3.00	3.00	3.00	5.50	3.00	5.50	5.50	3.00
Wilderness										
Wilderness use	RVD	8.00	8.00	8.00	8.00	10.00	8.00	12.00	12.00	8.00
Wildlife and Fish										
Hunting, big game	RVD	21.00	25.20	16.30	17.05	21.00	16.80	17.85	17.85	18.90
Hunting, waterfowl	RVD	24.00	32.00	26.40	32.00	28.00	20.80	23.20	24.00	19.20
Hunting, small game	RVD	24.00	32.00	24.00	22.40	27.20	24.80	20.80	24.00	32.00
Hunting, upland birds	RVD	24.00	32.00	24.80	21.60	28.00	21.60	20.80	21.60	24.00
Nature study, wildlife (nongame use)	RVD	29.00	21.75	29.00	29.00	29.00	29.00	29.00	29.00	29.00
Fishing, cold water	RVD	15.75	15.75	15.20	14.70	15.75	14.70	14.20	16.80	15.75
Fishing, warm water	RVD	15.75	21.00	16.80	21.00	17.30	17.85	14.20	16.30	—
Ice fishing	RVD	15.75	21.00	21.00	15.75	17.85	21.00	—	19.95	21.00
Fishing, salt water (anadromous sport fishing)	MLBS	58.50	—	—	56.55	46.80	56.55	—	50.70	40.95
Range										
Grazing use (livestock)	AUM's	5.57	5.88	5.51	4.96	6.00	5.90	3.76	4.41	3.00

[1]Source: U.S. Department of Agriculture, Forest Service. Recommended renewable resources program—1980 update. FS-346. Washington, DC; 1980; 560 p. [Appendix C, economic analysis].

[2]Abbreviations used: AF—acre feet, AUM—animal unit months, HW—hardwood, MLBS—million pounds, RVD—recreation visitor-days, RW—roundwood, ST—sawtimber, SW—softwood.

Note: These values are periodically updated. Contact Forest Service, Washington Office RPA Group for updated estimates.

refinement should not be undertaken until some sensitivity analysis has been completed. The sensitivity analysis should determine the impact that errors in resource value estimates have on the selection of the most economically efficient fire management program level. The value estimate errors must be considered within the whole context of the C + NVC calculations for incremental program level changes.

Three factors tend to reduce the impact of value estimation errors for fire management program analysis. First, large errors are unimportant for resource categories that are not usually affected by fire. If fire seldom damages developed recreation sites, a large error in the value estimate of a recreation visitor-day at developed sites is not important. Second, value estimation errors are not important if suppression cost variations between fire management program levels is larger than the fluctuations in the net value change of resource outputs. Suppression cost fluctuations have overshadowed net value change in resource outputs in some cases (Schweitzer and others 1981). Third, the C + NVC criterion is a marginal efficiency criterion by its nature. It can be used to determine the efficiency of adding or subtracting an increment of the fire management program, but it cannot provide an efficiency estimate of the total program. The value estimate errors tend to cancel out in a marginal analysis since only the differences in C + NVC from one program level to the next are important. If, for example, the per unit value of a resource output was underestimated 20 percent, the net value change estimates would contain similar errors for every fire management program level tested. Since this would affect the C+NVC of all the program levels evaluated, the difference between C+NVC's at adjacent program levels would change by much less than the C + NVC of any one program level. The presence of the same per unit value in both the *with* and *without fire* resource output time stream also tends to cancel out resource value errors in the same way.

Some indications of the sensitivity of fire program efficiency can be drawn from previous studies. Timber and improvement losses contributed by far the largest component of the net value change in earlier studies (Schweitzer and others 1981, U.S. Dep. Agric., Forest Serv. 1981). Substantial errors in the per unit value in other resource categories would not have materially affected the NVC calculation, let alone the selection of the most efficient fire management program level.

Similar data accuracy concerns were expressed in the past about timber yield estimates used in the evaluation of silvicultural investments. Sensitivity analysis conducted by Mills and others (1976), however, showed that the internal rate of return to silvicultural investments analyzed in a marginal investment format were quite insensitive to wide variations in timber yield estimates. Data accuracy requirements must always be evaluated within the context in which the data will be used.

We recommend that for the economic efficiency analysis of fire management programs, the timber value estimates should be refined, particularly by including prices for salvaged timber, and estimates for the replacement cost of improvements should be derived. The RPA value estimates should be used for the other resource categories until they can be more thoroughly evaluated with sensitivity analysis in a prototype fire economic evaluation model.

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In analyzing fire management programs for their economic efficiency, it is necessary to assign monetary values to the changes in resource outputs caused by fire. The derivation of resource values is complicated by imperfect or nonexistent commercial market structures. The valuation concept recommended for fire program analyses is willingness-to-pay because it permits uniform derivation of resource values across all resource categories, and it represents the full economic value of the output to society. The process of measuring fire effects in program evaluations introduces implications unique to the resource valuation process. Sensitivity analysis can help determine the required accuracy of resource value estimates for a particular analysis.

Retrieval Terms: economic analysis, resource values, fire economics, willingness-to-pay valuation, sensitivity analysis, fire effects, fire management.