BENEFIT-COST ANALYSIS AS APPLIED TO INSECT PEST CONTROL PROGRAMS

by

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INTRODUCTION

Throughout history insects have been a mixed blessing in the forest. There are those that have aided man in his attempts to produce a forest to better satisfy his needs and wants. There are also those, such as the Southern Pine Beetle (Dendroctonus frontalis Zimm), whose activities have been counter productive to the goals of man. Generally, these detrimental insects, or pests, adversely affect man in one or more ways. Not only do they reduce the quantity and quality of wood we get from our forests, but some of them also affect the volume and quality of water we receive. In addition wildlife, recreational, aesthetic, and other values can be reduced by these pests.

Past Efforts

Although these pests always have been, and probably always will be, with us, man has not stood idly by and let them do what they will. Through the years he has sprayed, cut, burned, inspected, trapped, baited and introduced predators - all in an attempt to control or eliminate them. Unfortunately, man has not always carried on this war to his best advantage.

Many foresters have practiced pest control with the philosophy that "the only good insect is a dead insect". This kind of thinking can lead to over-kills of pest species to the point where marginal pest control costs are greater than the marginal benefits, and non-pest species are decimated. Obviously, this kind of "forestry" is not only uneconomical, but can also lead to other sever ecological consequences.

Recognition of this danger prompted specialists in forestry related disciplines, such as biology and entomology, to speak out against these wasteful practices. Although many of these men have made progress in defining the physical relationship between insects and their environment, they often came up short when attempting to apply their results in a way that would maximize, to man, the return to their efforts. Whether it was because practical economic tools did not exist or because their existence was not widely known is not clear to this author. However, for whatever the reason, some scientists have proposed methods of analyzing the value of pest control programs that were either economically incomplete or inaccurate.

An example of this situation is found in the entomological concepts of "economic threshold" and "economic-injury level". As defined by Stern, et al., the "economic threshold" of an insect is "The density at which control measures should be determined to prevent an increasing pest population from reaching the economic-injury level." (12) The economic-injury level is defined as "the lowest population density that will cause economic damage." (12)

Stern (11) later reviewed these concepts and concluded that the original definitions of economic threshold and economic injury level were over-simplifications of the problem. However, he maintains that the key to an economic threshold is the difference between a presence of the insect and a density that will cause a 'reasonable' loss. Although he recognizes that the term reasonable is very vague, he maintains it is justified because "pest control is not as simple as comparing the cost of the chemical and application against an equal return."

In essence, the author feels Dr. Stern is pointing out that the entomologists realize there are costs and returns other than those mentioned by Dr. Stern, but the economic tools that measure these costs and returns either do not exist or have not been put into wide use.

While elementary economics points out that the amount of pest control to use is the amount that will equate marginal costs and marginal returns, this does not tell us how to measure these costs and returns. That a method for measuring these costs and returns is needed is illustrated by the works of Stern (11,12). No doubt the intentions of the entomologists were honorable when they ventured into the field of economics. Nonetheless, concepts such as "economic threshold" and "economic-injury level" underscored the need for the development of economic tools that forest managers could use to evaluate the worth of on-going and proposed pest programs.

Today's Management Needs

The "only good insect is a dead insect" philosophy has been largely overcome over the years, due to a massive research and education effort. However, the misallocation of resources is a very real problem despite the fact that millions of dollars and countless manhours have been expended for pest research and control programs.

This misallocation of resources result in part from the failure to recognize that effective, rational pest control involves a two step analytical process. First, physical and biological data about the insect must be gathered. This includes information about the life cycle of the insect and its relationship to the forest ecosystem. This information will hopefully enable scientists to formulate methods of controlling population densities.

Second, the costs and returns of the control methods must be analyzed to determine the course of action yielding the highest net return. In other words, the most promising physical possibilities should be analyzed to determine which is economically feasible.

Unfortunately, many management decisions are based almost exclusively on the physical and biological information gathered in step one. This must change if we desire effective and rational pest control.

This is not to say that more physical and biological data are not needed. Knowing how to manage forest pests so as to maximize the growth of the forest is not enough. The only thing that gives the forest value is the utility that man derives from it. Therefore, a forest manager must have a way of analyzing the resources used for forest management to be sure that the utility of those contributing the resources will be maximized.

Measuring man's utility is one objective of economic analysis. Logically, then, economic tools must be used by those responsible for choosing pest control programs. Only in this manner can these decision makers properly evaluate their alternatives in light of how they will affect man's utility.

A Promising Economic Tool

This thesis will be devoted to an economic analysis of forest pest control programs on public lands since a large proportion of this nation's forested land is controlled by state and federal governments.

A tool developed in the last four decades to assist the decision makers in the public sector is benefit-cost analysis. In principle this is a very simple concept. Merely sum the value of all the social benefits that accrue from a particular project or plan of action, subtract the social costs of implementing the project or plan, and you have the net social benefit. Although simple in concept, benefit-cost analysis requires careful thought and action. The analyst must be constantly aware of such pitfalls as double counting or using market prices that don't reflect social values, not to mention the theoretical and practical problems that can arise when attempting to identify and quantify social variables.

Despite the dangers, however the author attempts in this thesis to develop a benefit-cost outline that forest managers can use in evaluating alternative insect control programs.

Objective

The objective of this study is to identify the social benefit and cost variables associated with forest insect control programs, and to justify, based on economic principles, their inclusion in the benefit-cost outline. Finally, these variables will be organized in such a manner that forest managers will be able to readily evaluate the social worth of alternative pest control programs, once the variable values have been determined.

Literature Review

The concepts of "economic threshold" and "economic injury level" as originally presented by Stern, Smith, van den Bosch and Hagen (12) and reviewed and updated by Stern (11) represented an attempt by entomologists to use economic analysis to determine minimum acceptable levels of insect populations. Unfortunately, this attempt was found to be woefully inadequate because it did not consider the cost of controlling insect populations, only the benefits gained from control.

The concept of subjecting federal capital investment proposals to some type of economic analysis in order to determine a net social value is not new. Dupuit (4) first recognized the need for such a tool, but for nearly a century little was done to further develop his original ideas. It was not until 1936, with the enactment of the United States Flood Control Act, that this country formally adopted the idea of considering all of the benefits of a project in evaluating its worth. This act said, in part, that a project could be implemented only if "the benefits, to whomsoever they may occur, are in excess of the estimated costs".

However, as pointed out in Dasgupta and Pearce (3), the 1936 act did not define what was or was not a benefit, or how to measure a benefit once it was determined as such. The first attempt at creating a uniform standard for estimating benefits and costs was the Proposed

Practices for Economic Analysis of River Basin Projects (13), (known as the "Green Book"), prepared by the Subcommittee on Evaluation Standards for the Inter-Agency Committee on Water Resources. These standards have been revised several times over the years, with the latest federal guidelines being the Water Resources Council's Principles and Standards for Planning Water and Related Land Resources (16).

Although there is still dispute among economists over some of the principles underlying benefit-cost analysis and the way it is applied, Maniate and Carter (9), Mishan (10) and Dasgupta and Pearce (3) all agree that, to date, no better method for evaluating the social net worth of public capital investments has been developed.

SOME ECONOMIC CONCEPTS USED IN BENEFIT-COST ANALYSIS

To analyze the social worth of any project an analyst needs to identify the social benefits the project will produce, discounted to the present, then subtract the associated, discounted, social costs to obtain the net social benefits. The feasibility of a given project can be determined in this manner or several proposals can be ranked according to the level of net benefits they generate.

Although the general procedure is straightforward, the economic theory used in determining the social benefits and costs must be thoroughly understood and accurately applied. In this section seven different concepts used in benefit-cost determinations will be discussed. The reasons for their use and a brief review of the economic principles upon which they are based will be presented. These seven are, in order of presentation: consumer's surplus, social discount rate, shadow prices, characteristics of costs, characteristics of benefits, external effects, and risk and uncertainty.

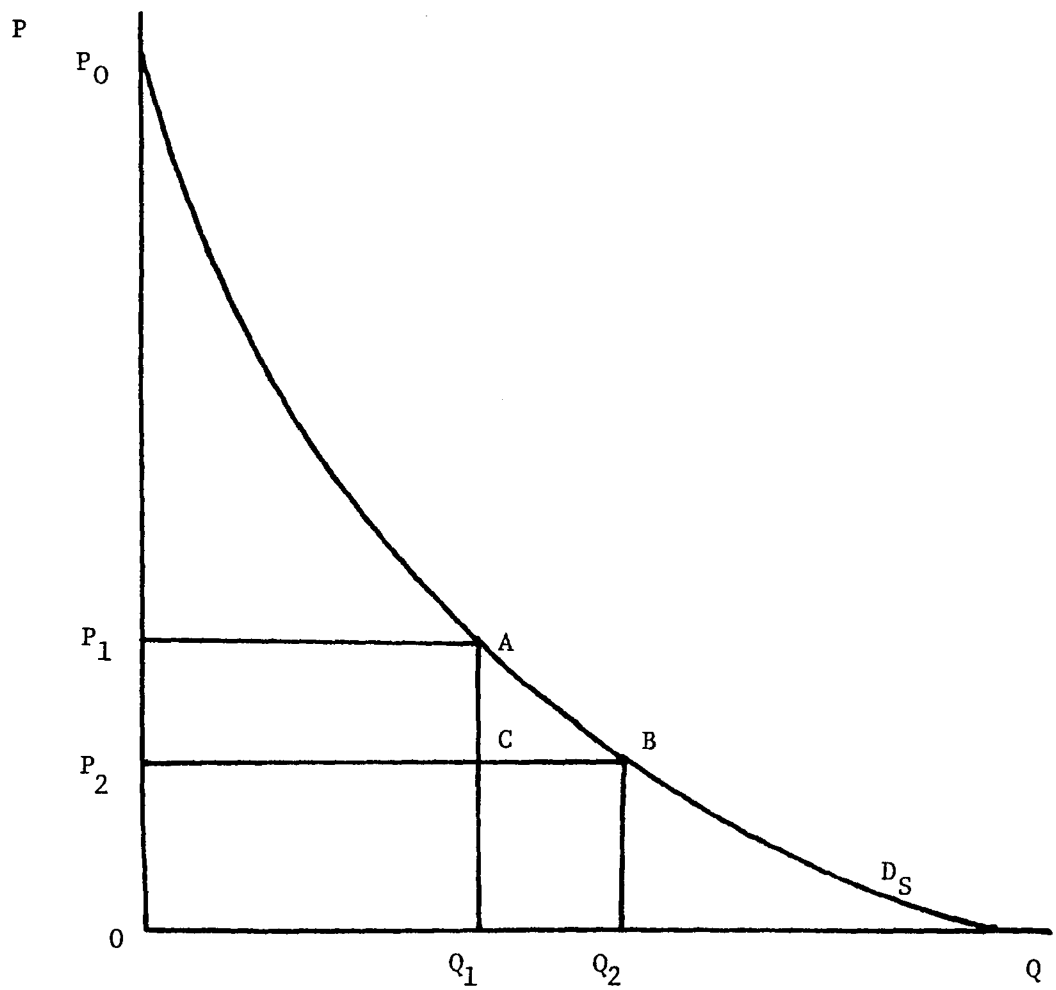
Consumer Surplus

Consumer surplus is that amount consumers are willing to pay for a good over and above what they actually do pay for it. While consumer's surplus has little applicability to the profit maximizing firm in a competitive market, it reflects the social benefit dervied from public investments.

There are three ways in which the consumer's surplus helps to determine the total social value of a benefit. First, it is used to find the value of a social benefit that is not reflected in the market price. In figure 1, given the social demand Ds, price P1, and quantity consumed Q1, the price system reflects a benefit equal to the area 0,P1,A,Q1. However, all members of society to the left of A on the demand schedule were willing to pay more for Q than the going market price. Therefore, the total social benefit is given by the market value of the product sold plus the consumers surplus, or the area (0,P1, A,Q1) + (P1,P0,A).

Although figure 1 assumes the demand schedule can be quantified this is generally not the case, especially when considering the demand for non-market goods such as a recreation experience. Clawson and Knetsch (2) discussed at some length the derivation of the demand schedule for non-market goods or services.

Second, consumer surplus enables the analyst to calculate the total effect price changes have on the social benefit dervied from a good or service. Again from figure 1, if the price of Q should move from P1 to P2, the change reflected by the market price is the difference in the areas P1,A,C,P2 and C,B,Q2,Q1. Considering the consumer surplus, though, the total change in social benefits is the difference between 0,P0,A,Q1 and 0,P0,B,Q2. Obviously, then, when the consumer surplus is calculated into the effect of price changes, the magnitude of a price change effect may be greater than the results obtained from considering only the change in market price.



D_S = social demand for Q
P_1 = original price of Q
P_2 = new price of Q
Q_1 = quantity of Q taken at P_1
Q_2 = quantity of Q taken at P_2

Figure 1. Effect of price changes on social benefit

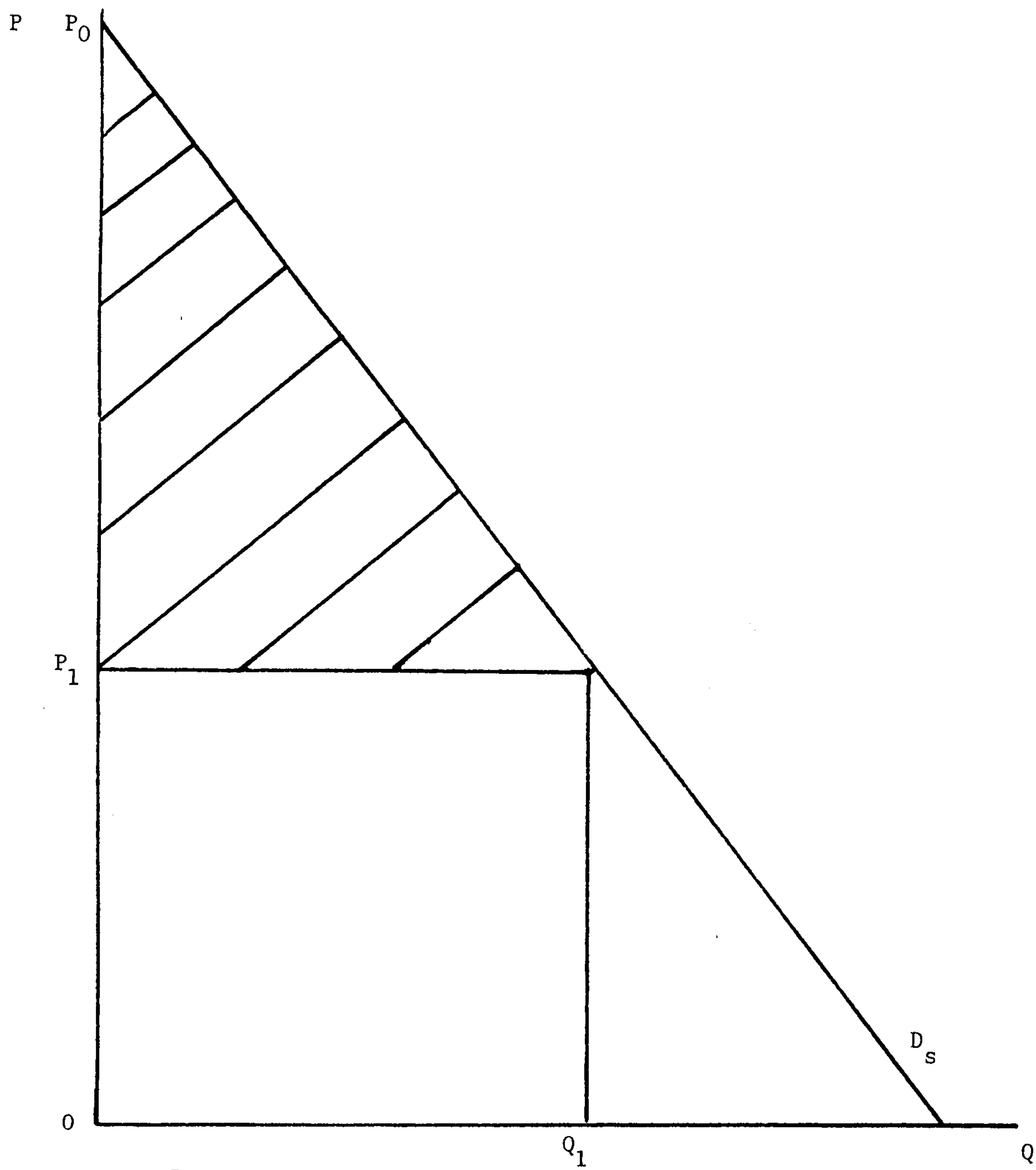
Third, in the case of products that have no established market price, such as a days fishing on a fee free reservoir, the analyst can value the benefit if the social demand schedule, Ds, can be derived. In this case, total social value = consumers surplus = area under the demand schedule.

A final note on the value of consumer's surplus. Many times the market value of a good does not reflect its true market value. For example, windthrown timber may be sold at a reduced price just to get it off the ground before it rots. Even though the market value of the timber is not reflected in the price, when the consumer surplus is added to the selling value of the timber this underestimation of the true market value is taken into account.

This, of course, assumes that the consumer's surplus can be calculated. If, as illustrated in figure 2, we can assume a linear demand schedule, the calculation is easy. The value of the consumer's surplus would be $\frac{(P_0-P_1)(Q_1)}{2}$. However, in most applied situations the demand curves, even if it is known over the entire price range, will not be linear. In such a case perhaps the best one can do is assume a linear demand schedule and recognize there is some error in calculations.

Social Discount Rate

As with any investment where costs and/or returns will be spread over more than one accounting period, the values must be discounted so that the net worth of alternative courses of action may be compared



D_s = social demand

P_1 = price of Q

Q_1 = quantity of Q taken at P_1

Figure 2. Calculating consumer's surplus

at a common point in time. However, the correct method for determining the social discount rate has not been agreed upon by all economists.

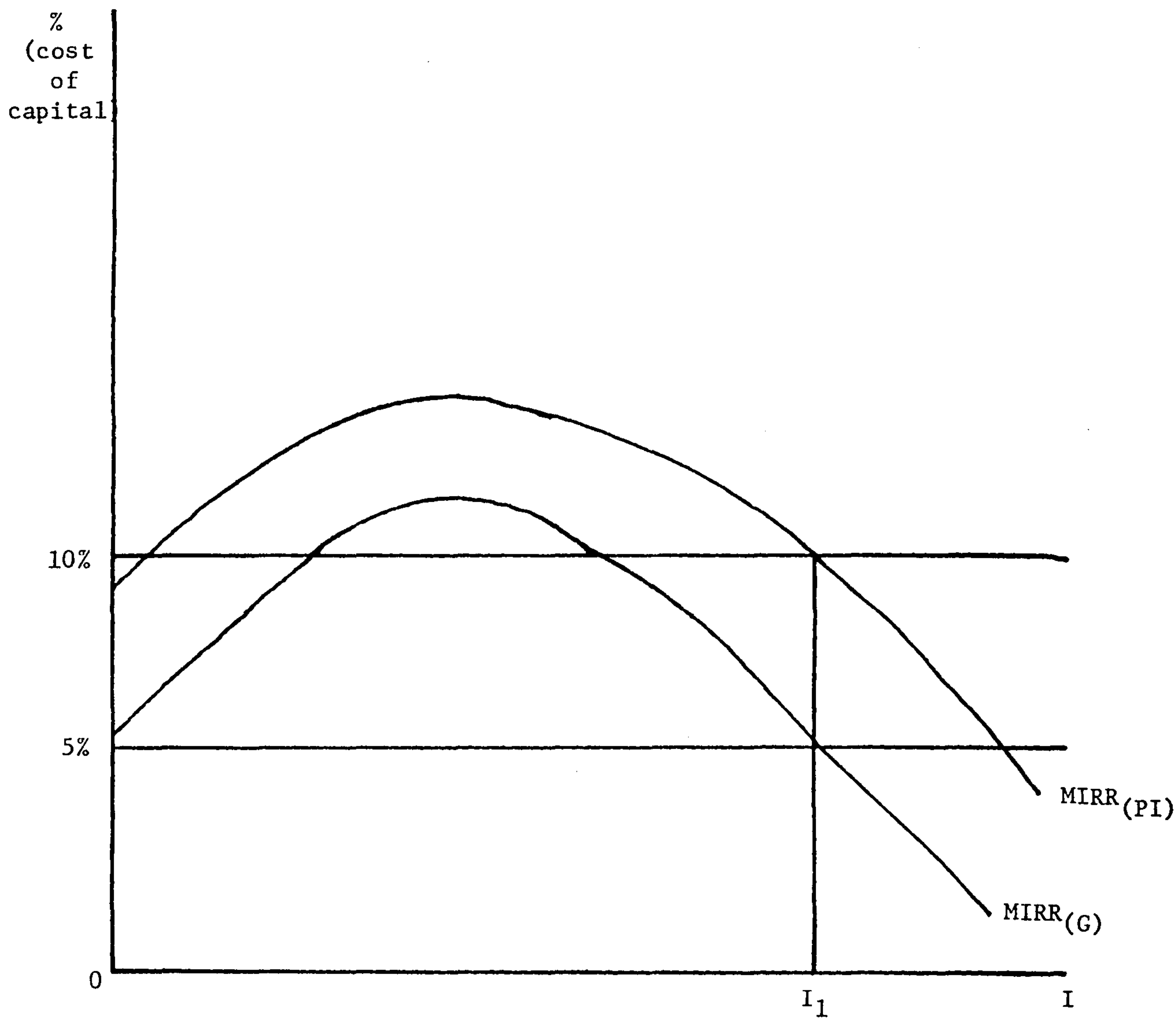
There are two different means of determining the social discount rate that have gained considerable recognition--the opportunity cost approach and the social time preference approach.

Opportunity Cost Approach

Advocates of the opportunity cost approach contend that capital investment funds are not unlimited. Therefore, when the government undertakes a project some other project, presumably in the private sector of the economy, must be foregone. Therefore, the public investment should earn at least as much as the private investment or the public investment should be foregone. However, there are two drawbacks to a straight comparison of return rates.

First, there are many different market rates for investment capital. The difference in the rates is assumed to be different risk premiums for different investments. Since public investments are usually considered to be low-risk or risk free, they cannot be fairly compared to higher risk projects in the private sector by looking only at the marginal internal rate of return (MIRR). Figure 3 will illustrate the point.

Suppose that private industry and the federal government both had project proposals that would require the last I_1 units of investment capital in a given year. If the cost of capital to private industry is 10%, and the government project is compared at the same rate, then the industry project is preferred, because at investment level I_1 the MR = MC for industry (point A), but MC MR for the government (point B).



$MIRR_{(PI)}$ = marginal internal rate of return for private industry
$MIRR_{(G)}$ = marginal internal rate of return for government investments
I_1 = total units of investment

Figure 3. Comparing MIRR to cost of capital

However, if the cost of capital to the government is actually lower than to private industry, the government project can be fairly evaluated at its own cost of capital level. In this instance, if it is 5%, there is no difference in the two investment opportunities because at investment level I_1 MC = MR for both the private industry and federal government proposals.

Second, market rates of interest do not reflect the true social return from investments. Therefore, the market rates would have to be adjusted to account for consumer's surplus, external effects and shadow prices if they are to be accurate.

Social Time Preference Approach

Dasgupta and Pearce (3) define social time preference as "a preference which society supposedly exhibits for present benefits over future benefits." In other words, consumers prefer $1.00 worth of benefits now rather than at some future date. How much society prefers present benefits is the conversion rate, or discount factor, that must be applied to all future benefits to arrive at their present value. But what is this discount rate?

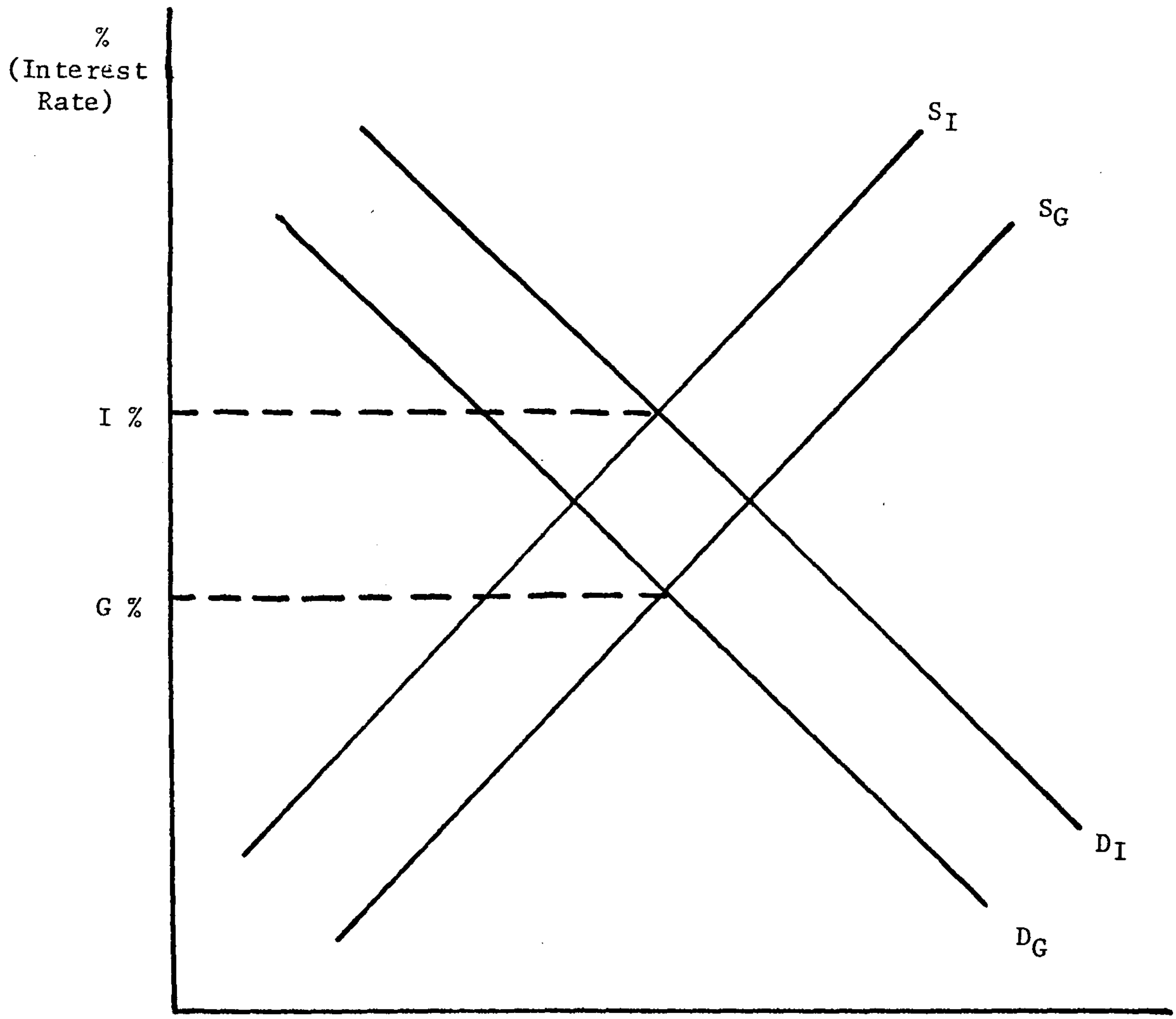
Proponents of the social time preference rate feel it should not include the risk premium associated with human mortality because we are dealing with society as a whole rather than individuals, thus, the risk premium associated with possible death before benefits are realized is irrelevant. The only risk is that the future goods or services may not come about. This is reflected in the demand schedules in figure 4. At every investment level the return required by society (D_G) is less than that required by individuals (D_I).

However, this is only half of the story. Both individuals and society (government) must borrow investment capital from the same pool of lenders. Since, as discussed above, government projects are considered less risky than other, at any investment level lenders are willing to supply capital to the government at a lower rate than to industry. This results in two supply curves, S_G for government and S_I for industry. The intersections S_I, D_I and $S_G D_G$ give the quantity of capital available and the cost of that capital for private industry and government, respectively.

The government borrowing rate, G%, is the rate that proponents of the social time preference approach feel should be used as a discount rate for government projects.

A Practical Choice

Mishan (10) and Dasgupta and Pearce (3) give further arguments for and against both methods. However, the author suggests that the social time preference rate be used. This recommendation is made on practical grounds. Pest control programs will most likely be funded and implemented by state and federal government agencies, and when the Water Resources Council published the Principles and Standards for Planning Water and Related Land Resources (16), they indicated that the federal borrowing rate would be used as the discount rate for all projects entirely or partially funded by the federal government. Thus,



D_I = demand for capital in the private sector
D_G = government demand for money
S_I = supply of capital for the private sector
S_G = supply of capital for government
I% = private borrowing rate
G% = government borrowing rate

Figure 4. Establishing private and government borrowing rates.

using the federal borrowing rate initially may save the analyst the trouble of re-evaluating his data in order to conform to existing funding requirements.

Shadow Prices

Mishan (10) defines shadow, or accounting, prices as ". . . the price an economist attributes to a good or factor on the argument that it is more appropriate for the purpose of economic calculations than its existing price, if any." The reason it is more appropriate is that the shadow price more accurately reflects the social value than the existing market prices.

In the evaluation of the net social value of pest control programs there are two types of situations in which shadow prices may be especially useful.

The first situation occurs where factors are present that cause a good or service to be sold at inflated or depressed prices. For example, where salvage timber is a product of forest insect attacks lega, biological or other factors may induce a timber owner to market his salvage timber at less than its true market value just to be rid of it. Unfortunately, recognizing when this type of situation exists or determining what price will reflect the true market value is never easy. It may be the case that one must rely on the best estimates of persons directly involved or on his own "feel" for the situation to arrive at a reasonable shadow price.

The second situation occurs when there is no market price at all. Such is often the case with recreation, wildlife, or watershed benefits and costs. While much has been written about the valuation of non-priced goods and services and many methods of calculation have been proposed, there is no universally accepted method of measuring them. The author feels that Clawson and Knetsch (2) have developed a very satisfactory method for valuing non-priced goods and services.

Characteristics of Social Costs

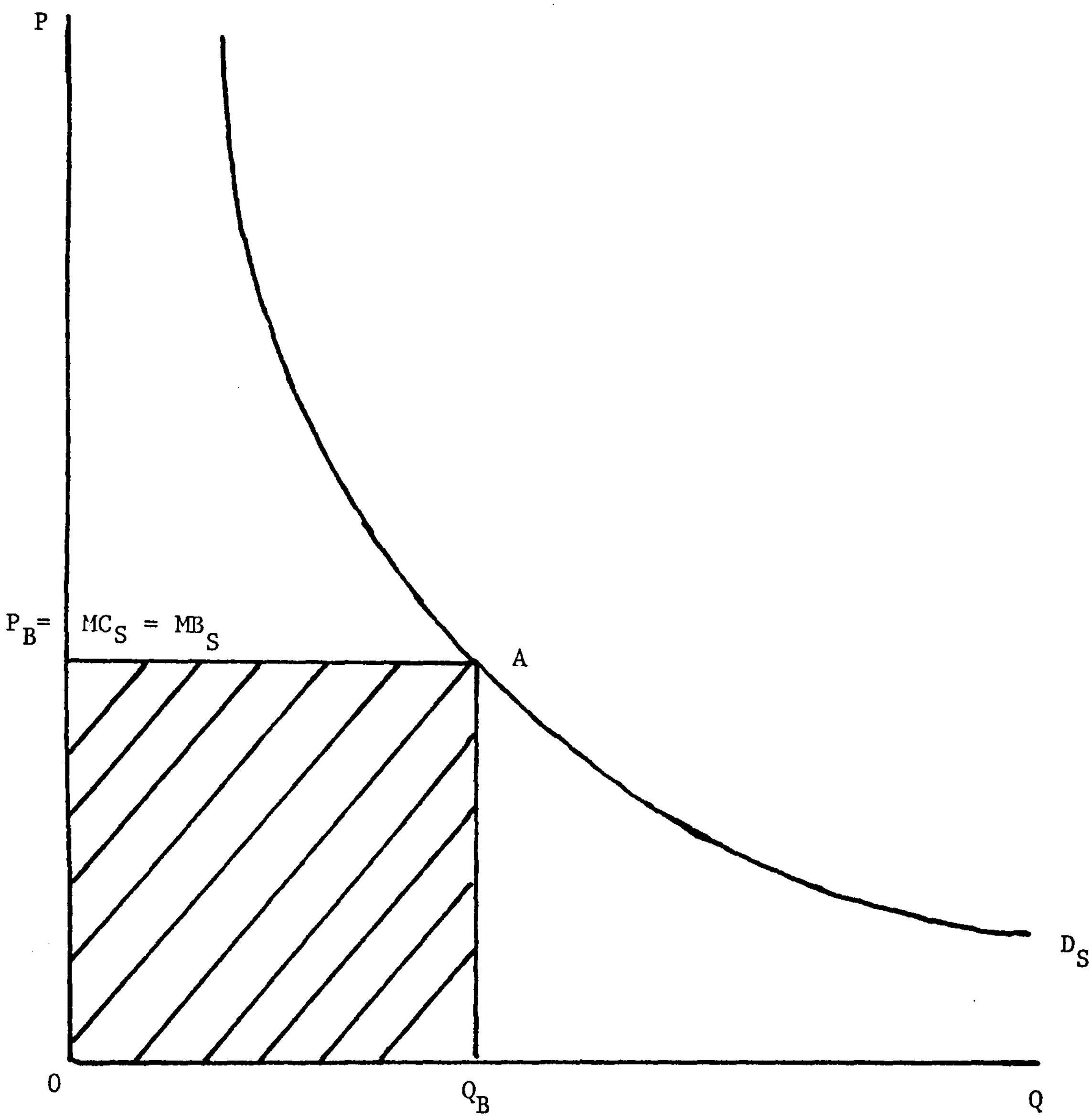
A simple totaling of accounting costs incurred will not necessarily reflect the actual social costs. There are both practical and theoretical reasons for this. In this chapter the economic theory behind the identification of social costs will be discussed.

The social cost of any investment is generally assumed to be equal to the opportunity cost of that investment. According to Ferguson (5), "The alternative, or opportunity cost of producing one unit of commodity X is the amount of quantity Y that must be sacrificed in order to use resources to produce X rather than Y. This is the social cost of producing X."

For most resources employed in an investment scheme the social, or opportunity, cost is assumed to be equal to the money required to bid the resources away from alternative uses. The rationale for this is as follows. Suppose a government agency needs to implement a program to suppress a certain insect, and that the agency must select one of two programs, A or B. For the agency to select program A means that the benefits derived from B will be foregone, so the social cost of project A is the value of the benefits not realized from program B. Now the problem is to measure this social cost.

Had problem B been chosen, it would have produced certain outputs, Qb, in figure 5 for which society would have been willing to pay a price, Pb. Since Pb reflects the marginal social benefit of B, the total willingness to pay for B, ignoring for the moment consumer's surplus, is Qb,O,Pb,A. Given that society is willing to pay this amount for program B, it is assumed that this amount of money is needed to bid resources away from program B to program A. That is, society is willing to pay the value of the benefits lost in program B in order to receive the benefits of program A. Therefore, the social cost of program A is the dollar cost of obtaining the resources used in the program. There are, however, some exceptions to this assumption that should be noted.

It sometimes happens that the price paid for a factor of production does not reflect its true social cost. For example, in an economy that is not fully employed there may be laborers willing to work (involuntarily unemployed) for whom there is no productive position available. Now, if a program is initiated which creates a paying job for this individual, his employment entails no social costs because his being employed in the new job did not preclude the production of any other good or service. Therefore, his wages would only be an accounting cost - there is no opportunity cost attached to this persons labor. This same argument will hold for idle land or any other resource that has no opportunity of being employed elsewhere.



P_B = price society willing to pay for benefits of program B
Q_B = level of benefits provided by B
D_S = social demand curve
MC_S = marginal social cost
MB_S = marginal social benefits

Figure 5. Investment opportunity costs

Another pitfall for the benefit-cost analyst to be wary of when calculating the social cost of an endeavor is the intangible opportunity costs associated with some resources. These intangible costs are ones that occur when one or more members of society give up some measure of their benefits, but the value of these foregone benefits is not reflected in the market price of the resources used to produce these benefits. This usually occurs when the benefit given up has no market value.

As an example of this category of social cost, consider a state forest consisting of 10,000 acres of timber, 5,000 of which are open to hunting and 5,000 which are not. However, the game in this forest are free to roam the entire acreage, giving them a 10,000 acre habitat. One day the governor of the state decides to convert the non-hunted half of the forest into a park designed for high intensity use. This action effectively eliminates half of the habitat for game, in turn eliminating half of the game available to hunters in the remaining 5,000 acres. Obviously, then, the hunters who use this forest have incurred a loss in benefits, or cost, as a result of creating the park. However, this type of loss - loss of the hunting experience - has no readily identifiable market value, and is not reflected in the accounting costs associated with the development of the park. It is thus an intangible social cost.

Unfortunately, these intangible opportunity costs are often difficult or impossible to measure for three reasons. First, these costs can often be incurred without the individual or agency responsible for analyzing a project being aware of their existence. Second, it is often very difficult, or impossible, to assign a value to those intangible social costs of which an analyst is aware, because the value of these costs varies so much from one individual to the next. Third, market prices for these costs are often non-existent.

Although an analyst may encounter much difficulty in recognizing and valuing intangible social costs, every reasonable effort must be made to do so nonetheless. Not only would the omission of these costs overstate the net benefits to be gained from a project, but in many cases it is the effect of these intangibles that may decide the social worth or uselessness of an investment possibility.

The opportunity cost is the social cost of an investment. Accounting costs reflect the opportunity costs only if three conditions hold: the market price of resources reflects their true value; no resources are employed at a higher value than their opportunity cost; and no intangible costs are incurred. *

If market prices do not reflect the true value of a resource, a shadow price can be assigned to the resource for the purpose of the analysis. This, of course, presupposes knowledge of the aggregate demand schedule for the resource and implies that the analyst is aware that factors exist which cause a different market price.

Measuring intangible costs is a problem economists grapple with at great length. Clawson and Knetsch (2) gave a good review on the measurement of intangibles. Through the measurement of intangible costs costs if often difficult, every reasonable effort should be made to establish a value for them. In many cases, however, their measurement is impossible, and the analyst must resign himself to acknowledging their existence and recognize that his costs are underestimated by the amount of their opportunity cost.

Characteristics of Social Benefits

From the study of elementary economic choice and utility theory one learns that individuals will, if acting in a rational manner, rank their available alternatives according to some sort of ordering scheme. In this manner they explicitly, or implicitly, indicate the relative utility of their alternatives, with the highest utility going to the highest ranked, or most preferred, alternatives, and so on down his list, or utility index.

If an individual is at state X on his utility index, and has the option of remaining at X or moving to Y, he will move to Y only if Y is ranked higher on his utility index. That is, he will only move from his present state to another state if the move is a "benefit" to him. A benefit, then, is any good or service that enables an individual to move to a state that is more preferred than his present state.

Moving to benefit-cost analysis, a social benefit can be defined as a good or service that allows society to reach a state that is more preferred than its present one. While knowing the definition of a social benefit is a necessary condition for conducting a benefit cost analysis, it is by no means sufficient. Beyond knowing the definition, an analyst must be able to recognize a social benefit for what it is. And for accurate recognition of social benefits the analyst must successfully identify all tangible and intangible benefits as well distinguish between benefits and transfer payments.

Tangible Benefits

A tangible benefit will be defined as any social good or service for which there is an identifiable or readily determinable market price. As a general rule, tangible benefits are readily identifiable. However, some difficulty may be encountered in ascertaining the magnitude of the benefit (how many bd. ft. of timber will a pest control program save?) or in confusing them with transfer payments. Therefore, all market prices should be examined carefully to insure they accurately reflect the value of the product (excluding consumer's surplus). As mentioned in the section on shadow prices, recognizing when market price are inaccurate measures of market value is always difficult and often impossible. Although it is hardly scientific, an analyst often must rely on his feel for a situation to make estimates of shadow prices. This is one good reason why an analyst should investigate a situation first hand rather than rely solely on data sheets for information. In addition, all potential benefits must be closely scrutinized to insure they are not just a transfer of benefits from another segment of society.

Intangible Benefits

The major difference between tangible and intangible benefits, from the standpoint of economic analysis, is that the former has an identifiable market value and the latter does not.

Clawson and Knetsch (2) outlined a method for establishing the value of non-priced recreation resources based on demand analysis. Very briefly, they derive a demand curve for a particular resource as a function of money, time and travel. Although this technique can give a good estimate of the demand based on money costs, it underestimates the total demand for the resource. This is due to such effects as alternative recreation uses and the difference in travel time for the resource users. Even though these techniques were formulated for deriving the value of non-priced recreation resources, I believe they are appropriate here because these techniques can also be used to estimate the value of intangible wildlife, watershed, soil and esthetic benefits associated with pest control programs.

After developing the above technique Clawson and Knetsch discussed several other methods of resource demand determination that have been developed. These include the Gross Expenditure method, Market Value of Fish Method, Cost method, Market value method and Direct Interview method. Since each of these methods contains one or more theoretical flaw that is more damaging to the accuracy of the value estimation than their method, the Clawson-Knetsch method of non-priced resource value determination is recommended as the most appropriate.

Transfer Payments

A transfer payment occurs when a good or service is transferred from one individual or group to another individual or group with a zero net change in the welfare of all parties concerned. This is an extremely important concept in benefit-cost analysis because what often appears as a gain or loss on a regional scale is just a transfer payment on a national scale. Two practical illustrations of this concept involve welfare payments and taxes.

Let us suppose that a pest control program in region A is expected to employ X number of laborers now drawing $100,000 annually in welfare payments, and that the gross dollar benefits of the project are estimated at $1,000,000 annually, $50,000 of which will be paid in federal taxes. The elimination of the welfare payments cannot be considered a benefit of the program, since the money saved is only transferred from one segment of society, the now employed workers, back to society at large. Likewise, the taxes paid are not a social cost, merely a transfer of revenues from region A to society at large.

These are just two of the more common areas where what appears as a gain or loss on the local or regional scale may be only a transfer payment on the national level. Obviously, then, an analyst must carefully scrutinize all cash flows in his analysis to insure the gains, losses, and transfer payments are correctly identified as such.

External Effects

An external effect is a direct effect on the welfare of one individual or group that comes about as an incidental by-product of another individual's or group's activities, and this change in welfare is neither compensated or priced.

These effects, or externalities, can be handled in one of two ways. First, they can be internalized. That is, they can be priced. An example of internalizing occurred in recent years in the pulp and paper industry. The effluent poured into streams for many years represented an external cost to other users of the stream. When the public and federal outcry against this practice induced them to construct settling ponds and use other methods of cleaning their waste water, the cost of this pollution control to the companies represented the internalized price of this cost.

Second, although some externalities can be internalized there are many that cannot be. Many environmental and recreational externalities fall into this category. However, all reasonable efforts should go into quantifying these externalities for the sake of completeness and accuracy in the analysis. Unfortunately, no uniform method of measurement has been developed. The Water Resources Council offers little help in this matter. They only remind the analyst that ". . . an attempt should be made to measure the net income change resulting from such externalities. When this is done the methodology should be carefully documented . . ." (16).

In light of the uncertainty surrounding the valuation of non-priced externalities, we shall do as the Water Resources Council suggests. Whenever an externality is encountered in the development of this analysis the net income change associated with it will be estimated by using the economic tools most appropriate.

Risk and Uncertainty

Although these two concepts are technically different, in this paper risk and uncertainty will both be included in the term risk. The justification for this is the author's belief that no public investment is made without at least some good subjective probabilities for the chance of success.

It is unquestionable that there is some element of risk involved with projects that have benefits and/or costs in the future. However, the question that does arise is; what is the risk associated with each or the costs and benefits involved? Certainly it is not the same for all factors involved in the analysis.

First, the probabilities of any given event occurring must be determined, either objectively or subjectively. After the expected probability of an event is determined, the risk factor (r) is calculated using the formula:

$$r = Bf/Bp(1+i)^t$$ where,

r = risk discount premium

Bf = future value

Bp = present value

i = risk free discount rate

t = years discounted.

Distinguishing between benefits and costs realized in the public and private sector of our economy, Howe (7) has presented a way of handling the risk factor in the public sector of the economy that not only simplifies the procedure, but also appeals to one's logic. His presentation is as follows:

> "Arrow and Lind(i) have convincingly argued that project benefits and costs that accrue to the public sector are passed to the general taxpayer through the size of his tax bill. Such benefits or costs get spread over all the taxpayers so that, if the number of taxpayers is large, the element of uncertainty to each taxpayer is negligible. The present values of such benefits and costs may thus be evaluated in terms of expected values discounted by the risk free discount rate. . ."

This is consistent with the Water Resources Council's use of the federal borrowing rate, considered to be risk-free, as a discount rate.

IDENTIFICATION AND MEASUREMENT OF SOCIAL COST VARIABLES

While it is understood that the individuals in society are the ultimate bearers of all costs, society has set up certain agents whose responsibility it is to collect funds, assign job responsibilities, complete jobs and distribute funds for carrying out these jobs. To determine the social cost associated with a pest control program two preliminary steps should be taken to insure that all costs are accounted for and will reduce the chance of double counting.

First, all of the agents in society that spend funds for its members should be identified. Generally, one or more of four agents will be involved; the federal government, state governments, local governments, and private industry and individuals.

Second, these agents often do not spend funds directly, but instead distribute them to other agents for use in completing specific tasks. Herefore, the spending agent, the agent who collects funds directly from society, must be differentiated from the working agent, that is, the one that performs the job for society. Of course, in some cases the working and spending agent will be one and the same.

The total social cost, then, is the sum of the costs borne by each spending agent. This distinction will eliminate much of the possibility of double counting where cost sharing and direct grants are involved.

These first two steps are illustrated in figure 6. The total social cost is subdivided between the four spending agents of society. Below each of the spending agents is the possible paths that funds can

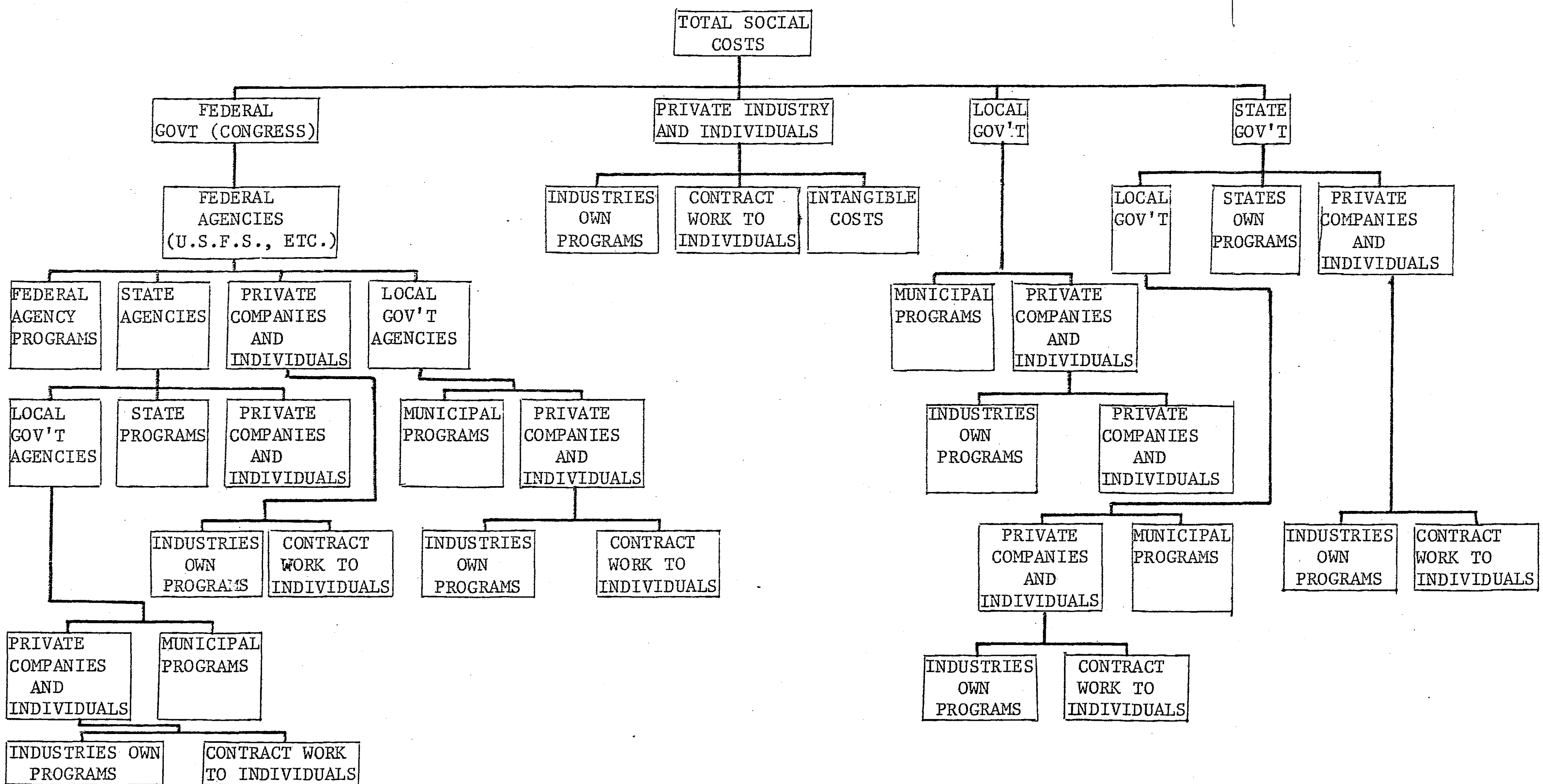


Figure 6. Distribution of Social Costs

follow to reach the working agent. For example, the federal government, acting as a spending agent may pass funds to federal agencies, such as the U. S. Forest Service, which in turn passes them on to state agencies, which may pass them to local governments, etc. until they reach the working agent using those funds.

In order to avoid double counting, then, the costs of a working agent for a pest control program must be traced to the ultimate spending agent. In this manner all costs will be charged to the proper agent and a single cost will not be charged to both the spending and working agent.

Planning Horizon

When considering an insect control program a planning horizon over which costs and benefits will be claculated must be determined. It must neither be so short that significant benefits or costs will not be included nor so long that the analysis becomes meaningless. For example, a two year horizon would eliminate most of the benefits of a forest insect control program, while a 200 year horizon would require estimation, of costs and benefits so far into the future that the range of possible error would render the results useless for most purposes.

Fifty years or one rotation length have sometimes been suggested as reasonable planning horizons. While either of these may be suitable for a particular problem, it is impossible to give a general rule of thumb that will apply to all cases. The planning horizon for each analysis must be decided upon the factors pertinent to that analysis, keeping in mind that the horizon should be long enough to incorporate the significant costs and benefits, but not so long that cost and benefit estimates cannot be made with a reasonable degree of accuracy.

Discount Rate

The reasons for using a discount rate and for recommending the federal borrowing rate are discussed in section two on pages 12-13. Although discounting will not be mentioned with the discussion of each variable, it should be understood that any cost that occurs in more than one year or in any year beyond the first year must be discounted to the present. Thompson (15) is one of the many sources of discounting formulas available to the analyst.

Proposed Budgets and Opportunity Costs

Proposed budgets are the most obvious and usually the most readily available source of cost data. However, there are certain limitations and pitfalls associated with proposed budgets that must be recognized and dealt with.

Often times actual expenditures do not match proposed budgets. Since it is not possible to predict the future with certainty, it is unrealistic to expect expenditure projections to always be accurate. One way of compensating for this is to compare past budgets of any agency to their past accounting records. From this a regression factor may be developed to apply to proposed budgets. If past records are not available the budget must be recognized as accurate only within some limits.

A second drawback to budgets is a result of the pressure administrators are under to match expenditures as closely as possible to budgeted funds. This can result in work being done for project A being charged to project B or vice-versa. Obviously, administrators would not be prone to revealing these types of shifts, so it is doubtful that their effect on a particular budget could be measured.

Third, market prices reflected in a budget may not reflect the true social value of the resources. Market interferences, such as wage and price controls, or other factors may alter the price of a resource. Again, though, unless there is an obvious market interference or other factor in evidence, it is doubtful the impact can be measured. On the bright side, though, except in the obvious case, the impact of price deviations on the results of the analysis will probably be insignificant.

Fourth, budgets do not differentiate between opportunity cost items and transfer payment items. All budget items need to be examined to insure that they are not wholly or partially transfer payments.

Fifth, budgets may be hard to obtain from private industries or individuals. These people are often concerned, understandably, that outsiders may not use the information with discretion or that the information may inadvertently fall into the hands of competitors.

Last, budgets do not reflect intangible costs. Even if a budget were a perfect measure of all other opportunity costs, it would still underestimate total costs by the value of these intangibles.

In summary, then proposed budgets are a good place to start in identifying and measuring social costs. However, several modifications must be made in the budgets before they become good estimators of the social cost of a pest control program.

Sensitivity Analysis

In some cases it may be impossible, or at least very costly, to determine where or by how much social costs vary from budgeted costs, or to correctly value intangible variables. When this is the case sensitivity analysis may help solve the dilemma of whether to strive for complete accuracy or settle for what is practically possible.

In essence, sensitivity analysis means trying different values for a variable to see how much the changes affect the outcome of the analysis. If the affect is slight, it is doubtful that much expense could be justified in furthering the accuracy of the data. Taha (14) is one of many sources that discusses the techniques of sensitivity analysis in some depth.

Cost Variables

There are three possible categories of costs associated with any insect control program. These are: research costs; detection costs; and control costs. Figure 7 gives a breakdown of the types of cost that are associated with each of the categories. Intangible costs are not included here because the author feels that government agencies and corporations do not incur intangible costs, individuals do. Therefore,

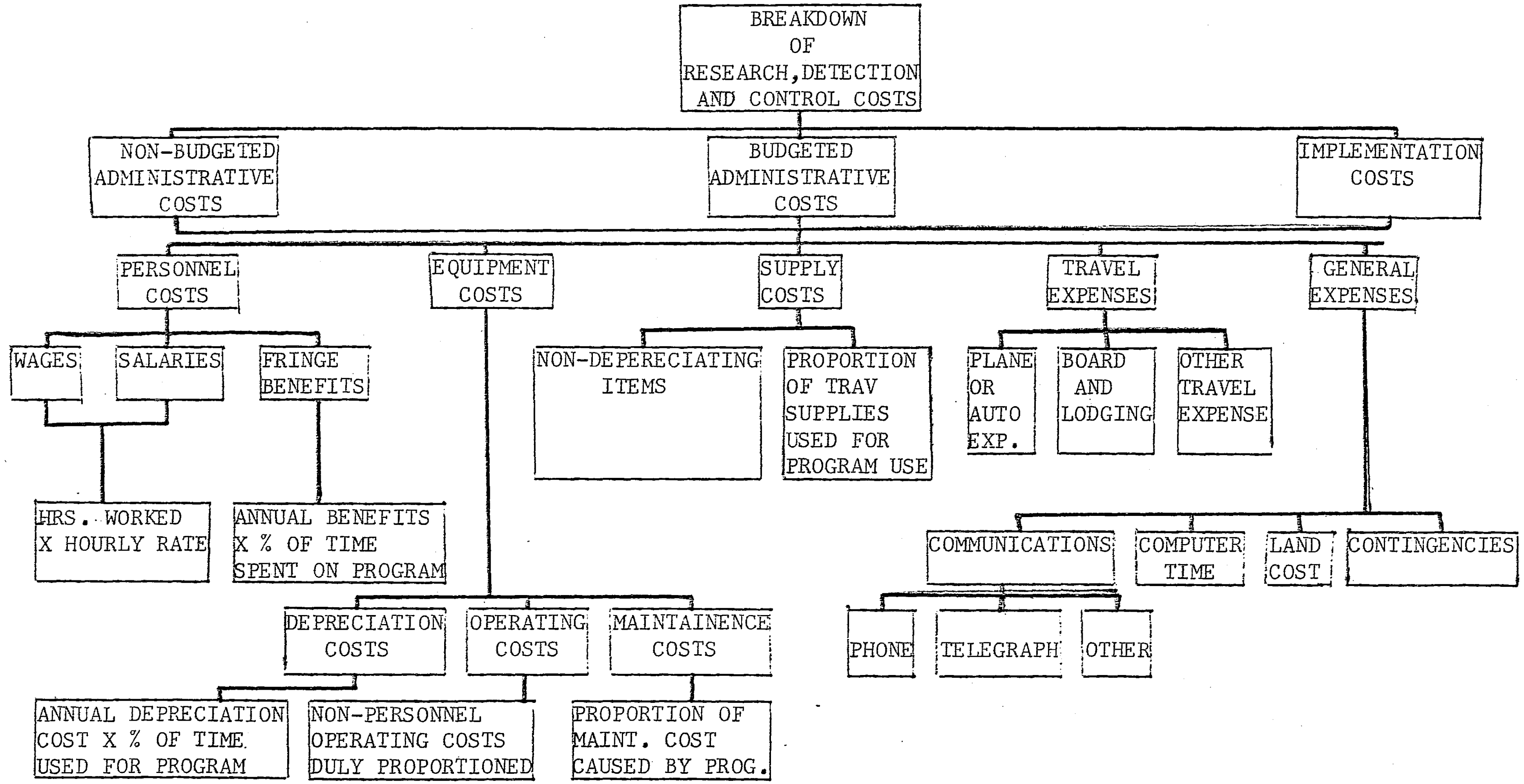


Figure 7. Research, detection and control costs

research, detection and control costs will be considered in terms of government and industrial institutions, and intangibles will be considered as a cost to individuals at the end of this section.

Notice, in figure 7, that there are two types of administrative costs. Agency administrative costs are those the working agent spends to carry out a particular program. Fiscal administrative costs are those incurred by a spending agency in administering funds to other agencies. This distinction is necessary because the latter administrative cost is not always reflected in a pest control budget. An example will help illustrate the point.

Suppose the U. S. Forest Service in Washington, D.C. is involved in twenty-five cost sharing programs with different states. The amount of money spent by the Forest Service administering each of these funds is rightfully an opportunity cost incurred by each of the respective programs. However, the Forest Service most likely has one 'administrative budget' under which all of these costs are lumped. Therefore, a separate box in the flow chart is allotted for these costs, primarily to remind the analyst that they exist and must be accounted for, even though they appear in no pest program budget per se.

Another point to notice in figure 7 is that all three types of costs, the two administrative costs and the implementation costs, further subdivide into the same categories. While this is generally the case, it is also true that these subdivisions will comprise a different proportion of the costs as you move from one type cost to the other. For example, you would expect equipment costs to comprise a much larger share of the implementation costs than of the administrative costs.

Research Costs

Since a university or other research agency usually receives a grant to do a specified piece of research, most research costs can be accounted for by listing the size of the grant. As one would suspect, though, some modifications must be made to this figure to get an accurate estimate of research costs.

As with any agency, research institutes rarely match actual expenditures with research grants to the penny and so research grants are subject to many of the flaws that exist in budgets. For any particular analysis, a sensitivity analysis of the impact of the variations from the value of the grants should be run first. If the analysis is sensitive to changes in the research costs, good cost data must be obtained.

Another shortcoming of the grant value is that it doesn't reflect the administrative costs of the source agent. These must be determined for any analysis.

Finally, the dollar value of the research grants must be adjusted by the net effect of externalities such as overhead costs and the social benefit of educating graduate students. However, this effect will usually be a small proportion of the total cost, and measuring it is nearly impossible. Therefore, the analyst can often assume the net effect of these externalities is zero, or simply recognize research costs are inaccurate by the net value of these externalities.

One of the difficulties as regards research costs is deciding which research activities should be charged to a specific pest control program. Should research that has an impact on, but is independent of, a project be charged to it? Although there may be some support for including these research costs in theory, the author feels they should not be included. Any research can have far reaching effects that are impossible to identify or quantify, so it is more feasible to assume that, for any one project, the cost of the unidentified research upon which the project draws is equal to the research benfits other projects will receive from the current project that will not be counted as a benefit of this project.

Detection and Control Costs

Detection and control costs are segregated from research costs because they are rarely included in a lump sum grant. They are aggregated for three reasons: they include the same types of costs; in practice, there is often a fine line between detection and control, making the separation of their costs impossible; and in most cases an agency involved in one activity is also involved in the other.

The main difficulties in tabulating detection and control costs will be practical ones. Some of the more common problems an analyst will face are listed below.

1. Budgets often do not differentiate between detection and control costs.

2. Expenditures are not always correctly allocated to budgets.

3. The work of several programs may be included in a single budget, which will require the analyst to determine the correct proportion of the budget to allocate to each program.

4. Some costs, such as fringe benefits (social security, insurance, etc.), are not included in pest control budgets.

5. Records may not be kept in a way that is useful to the analyst.

In theory, then, the identification and measurement of detection and control costs is rather straightforward. However, in practice the analyst may have to work in a round-a-bout way to arrive at the actual opportunity costs.

Other Tangible Costs

As can, and sometimes does, happen with any control program, costs can be incurred that were not planned. For example, pesticide may be applied to a stand of trees on a windy day, with toxic doses of it blowing onto farmer Brown's pasture, resulting in livestock losses.

These are legitimate opportunity costs of the program, and as such should be included in the analysis. However, because of their random and unpredictable nature it is virtually impossible to identify and measure them. Again, the analyst has recourse to one of two alternatives: either he can assume that the effects of unplanned costs and benefits negate one another, or he can simply state that his results will be in error by the net effect of these unplanned benefits and costs. The latter alternative is probably the more realistic approach and the one that will be of the most use to those who use the analysis for making planning decisions.

Intangible Costs

As indicated earlier, intangible costs fall on individuals, not government agencies or private firms. This is because an agency or firm is a tool designed by men to fulfill some function. Obviously, a tool does not "feel" intangible effects or costs, it is subject only to the tangible influences to which it is subjected.

The difficulties of identifying and measuring intangible costs are discussed on pages 20-22. It seems logical that, unless a program is dealing with urban forestry, intangible opportunity costs would be minimal at worst.

However, even though it may not be possible to measure these costs, the analyst should still note that his costs are understated by the amount of these costs. As with the random tangible costs, recognizing the existence of the intangible costs gives decision makers one more piece of information on which to base planning decisions.

Summary

Identification and measurement of social cost variables can be summarized in seven steps.

1. Identify the spending agents.
2. Determine all of the spending agents' budgeted costs for a program.
3. Modify budgeted costs as discussed in this section to obtain the true social opportunity costs.
4. Determine the source agents for all of the spending agents' funds.
5. Add any extra costs incurred by the source agents that are not reflected in the modified budgets of the spending agents.
6. Identify and quantify intangible costs associated with the program.
7. Sum the opportunity costs of the source agents and the value of the intangible opportunity costs to arrive at a total cost figure.

Finally, it should always be remembered that information costs money. Therefore, if a point is reached in the course of an analysis where there is a question as to whether or not additional information will pay its way, a sensitivity analysis of the cost variables involved is a good way to determine if the cost of additional precision is justified.

IDENTIFICATION AND MEASUREMENT OF SOCIAL BENEFIT VARIABLES

The first step in identification and measurement of social benefit variables is to determine the areas where potential benefits exist. The seven areas that will cover benefits in most any pest control program, as outlined by Leuschner and Newton (8), include: timber benefits; recreation benefits; esthetic benefits; watershed benefits; soil benefits; wildlife benefits; and grazing benefits. After discussing some general considerations pertaining to social benefits each of these seven areas will be dealt with in some detail.

Planning Horizon

Just as with the cost variables, and for the same reasons, a planning horizon must be established for the measurement of benefit variables. In addition, the planning horizon for cost and benefit variables must be the same if the analysis is to have any validity.

Discount Rate

Again, a discount rate is needed for benefits for the same reasons that it is needed for costs. Also, for the analysis to be meaningful, the discount rate for all costs and benefits must be the same. For the reasons presented earlier, the federal borrowing rate is suggested as the proper discount rate.

Timber Benefits

The potential timber benefits is the increased value damaged timber would have were the insect not present. These potential benefits are outlined in figure 8.

Mortality

Killed timber may or may not be a total loss. As figure five illustrates, there are four classes of benefits to be considered when dealing with timber mortality.

Non-salvable, merchantable trees - These are trees that are of merchantable size but for one reason or another cannot be salvaged. Perhaps the infestation spots are not large enough to make salvage operations economically feasible, or the timber may have been totally destroyed, economically speaking by the insect.

These trees are a total loss since man can salvage nothing from them. This loss, or potential benefit, is measured by multiplying the volume of timber killed by the green stumpage price. To be accurate in estimating benefits, however, the volume of timber must be sub-divided into use classes (pulpwood, veneer, etc.) in order to assign the stumpage price that is correct for each class. Generally, this can be done by determining the volume by dbh class and dividing the use classes into dbh classes.

Non-salvable, non-merchantable trees - Since these trees have no market value there is no loss incurred when they are destroyed by insects.

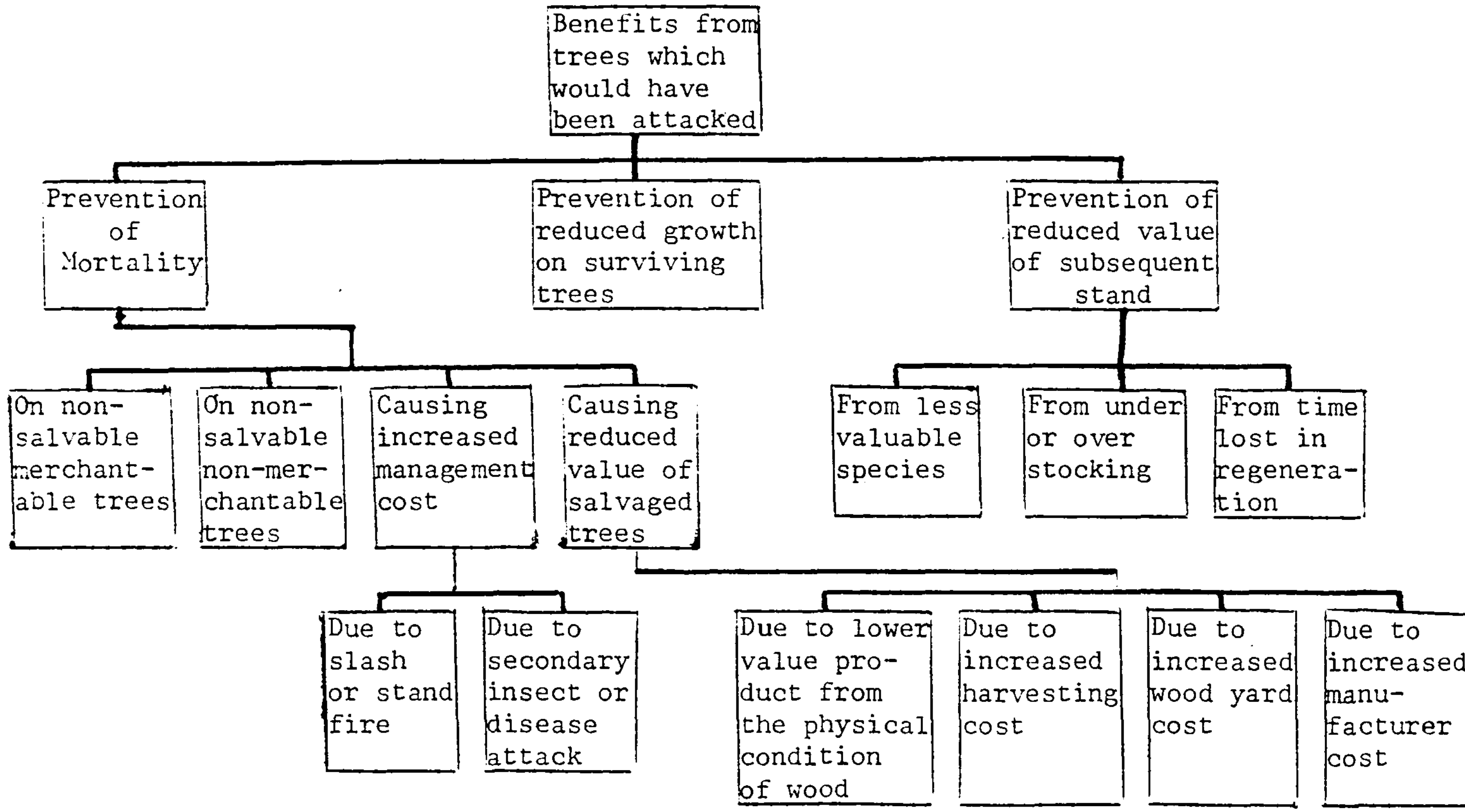


Figure 8. Potential timber benefits

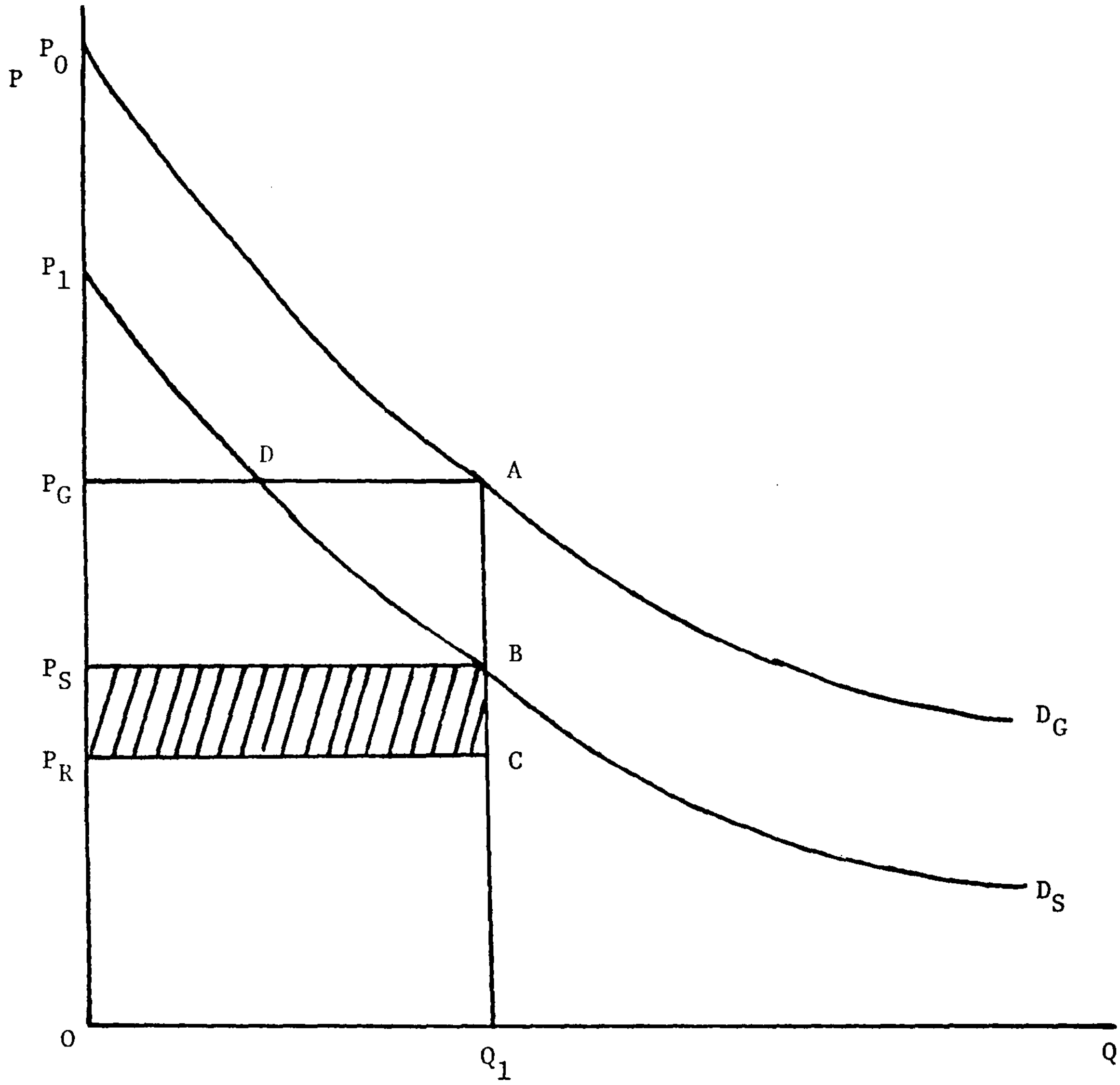
However, there is a loss due to the time lag necessary to regenerate and produce another tree. This loss will be accounted for in the subsequent stand analysis.

Increased management costs - The potential benefit here is the elimination of the excess management costs incurred as a result of timber mortality. Such costs may result from the need for extra fire protection or secondary disease attack protection, or the cost of removing timber to avoid these risks.

To measure this cost it is necessary to calculate the value of the administrative, personnel, equipment, supply, etc. costs that are used in performing this excess management.

Reduced value of salvaged trees - One way to handle this is to assume that stumpage is a residual and that all losses are reflected in the differential stumpage price between green and salvaged timber. Therefore, multiplying the volume of timber salvaged, by use class, times the stumpage differential price for each class gives the potential benefit. Unfortunately, there are several serious drawbacks to making this assumption.

First, the salvage price may not reflect the true market value of the timber. Pest control laws or other factors may induce a landowner to unload salvage timber at a price below the true market value just to get rid of it in a hurry. In this event the potential benefits would be overstated by using stumpage differential prices (figure 9).



D_G = demand for green timber
D_S = demand for salvage timber
P_S = market price of salvage timber
P_G = market price of green timber
P_R = selling price of salvage timber

Figure 9. Difference between market price and market value

Suppose a timber owner has Q1 volume of salvage timber to sell in a competitive market. Also, suppose that instead of selling it at the market price, Ps, he sells it at a reduced price, Pr. Area Pr, Pg, A, C would be calculated as the potential social benefit if stumpage price differential was the valuation criterion used. However, this would overestimate the actual social benefit because the area Pr, Ps,B,C is just a transfer payment from the timber grower to the timber processor. The true social benefit is the area Ps,Pg,A,B, plus the change in consumer surplus, area D,P_1,PO,A.

Second, stumpage may be only a partial residual. That is, all of the excess costs of processing and marketing the timber and timber products may not be passed back to the stumpage. One might suspect that this is the case, especially in periods of timber shortage or high consumer demand.

If there is evidence that excess costs are spread throughout the forest to finished product chain the analyst is in for quite a job in measuring the potential benefit. For each use class he must trace the costs and returns through the entire chain for both green and salvage timber to come up with a differential value per unit of stumpage input. On top of this, his calculations can be further complicated by changes in conversion rates into final products that may be associated with the salvage timber.

In light of the time and money it could take to complete an analysis of this type it may be prudent to run a sensitivity analysis on stumpage price differentials before jumping headlong into a price differential study.

Third, the stumpage price differential may not measure a potential benefit to society, but rather a transfer payment from the timber producer to the timber processor. For example, suppose a grower is selling green timber at $100 a thousand to a processor who is netting $100 a thousand profit. If the timber is attacked by insects and the grower must sell his timber at $50, but the processor maintains his same costs and sells the finished product for the same price, he has increased his profit to $150. Thus, there is no potential benefit to society in controlling the insect. There has just been a transfer of income from the grower to the processor.

In conclusion, while the stumpage price differentials are often suggested as measures of the potential benefit of salvaged timber, there are pitfalls involved with these prices that should be understood and avoided if possible. On the other hand, price differentials are relatively easy to obtain, which may make them the most feasible measure to use, unless the greater precision of more accurate data can justify the cost of obtaining it.

Reduced Growth in Surviving Trees

This potential benefit refers to trees that have not succumed to insect attack, but have suffered growth losses as a result of them. Losses can occur here in one of three ways.

First, the trees can be harvested at the regular rotation age but with a reduced volume. In this case, the loss would be the reduced volume of the trees multiplied by the stumpage price.

Second, timber harvest may be delayed until a desired volume is reached. In order to calculate the loss, the stumpage value of the harvested tree must be discounted back to the normal rotation age. This value is then subtracted from the value of unattacked stems of normal rotation age to estimate the potential benefits of eliminating the growth loss.

Third, the quality of surviving stems may be affected by the insect attack. The value of this loss is estimated by using the stumpage price of the lower value timber when calculating the growth loss by one of the two methods discussed above.

<u>Subsequent Stand Values</u>

This is the value of stands that are killed before the timber reaches a merchantable size. Assuming all other factors remain constant, the loss is the value of the extra time required to grow a stand of timber to rotation age. The steps required to calculate this loss are as follows:

1. Determine the present value of a perpetual string of unattacked rotations. This is done in the following manner. Compound all costs and returns, using the social discount rate as the interest rate, to the date of harvest for a single rotation. Next, subtract costs from returns to find the future net worth of a rotation. Finally, the present net worth of a perpetual string of rotations is found by using the formula $V_0 = \frac{R}{(1 + p)^{i-1}}$, where V_0 is the present net worth of the string of rotations, R is the net value of a rotation at harvest age, and i is the rotation age. This method assumes, of course, that all rotations will have the same net value and that the rotation age will remain constant. If they don't, the mathematics of the computation get messy but the principles are the same.

2. Compound the value found in 1 the same number of years as the age of the destroyed stand.

3. Subtract the value of 1 from the value of 2 to determine the loss.

While this procedure is straightforward, it is not accurate unless the subsequent stand is identical to the destroyed one and the destroyed stand had no value at the time of attack. If the two stands are not the same, and the original stand had some value, the net social value is found in the following manner.

Let us assume that after the insect has attacked and killed a stand the initial subsequent stand is of a different species composition than the original stand. Furthermore, after the initial subsequent stand is harvested, the site is returned to a perpetual rotation of stands like the original stands. In this case, the potential benefits are calculated using the following equations.

1) Value of string of rotations had no attack occurred

$$V_1 = \frac{V_m}{(1+i)^m-1} \times \frac{1}{(1+i)^{m-YA}}$$

$$OC = \frac{V_m}{(1+i)^{m-Yn}} - V_k$$

$$V_{UA} = V_1 + OC$$

2) Value of string of rotations after attack has occurred.

$$V_2 = \frac{V_m}{(1+i)^m-1} \times \frac{1}{(1+i)^P}$$

$$V_3 = \frac{V_P}{(1+i)^P}$$

$$V_A = V_2 + V_3$$

3) Potential benefit = $V_{UA} - V_A$ 1/

There may, of course, be variations of the way the stand is managed after attack. Nonetheless, the calculations would be essentially the same. The two changes that would have the greatest impact and the highest probability of occurring are changes in species composition and stocking level. However, these changes are not necessarily changes for the worse. If, in fact, step 3 above gives a negative result, then pest control would be a negative benefit.

1/ V_1 = Present value of a perpetual string of rotations like the present stand that are begun at the end of the current unattacked rotation.

OC = Opportunity cost of the stand lost to the insects

V_k = Net value of original stand at time of attack

V_{UA} = Present value of a perpetual string of rotations had no attack occurred

V_n = Net value of original stand at rotation

m = Rotation length of original stand

YA = Age of stand at time of attack

V_2 = Value of a perpetual string of rotations like the original stand that are begun after the initial subsequent stand

V_3 = Present value of the initial subsequent stand

V_p = Value of initial subsequent stand at rotation age

P = Rotation length of initial subsequent stand

V_A = Present value of this string of rotations that occurs after the insect attack

Recreation Benefits

As outlined by Leuschner and Newton (8) and illustrated in figure 10, there are three possible responses of recreators to an insect attack. Each of these responses - continued use of the recreation site, substitution of an alternative recreation site or discontinuing recreation activities - has costs, or potential benefits, associated with them.

Continued Use of the Recreation Site

For those people who continue to use the recreation site one of two situations can be said to exist. Either they derived no benefit from the uninfested trees, or the benefit is not as great as the cost of using an alternative site.

In the first case there is no social loss incurred at all. An example of this may be the vacationer who is traveling and just pulls his camper into a site for the night, or the high school band that uses a site for an evening cookout.

In the second case there is a social loss, but the measurement of it is difficult at best. In theory, the benefits are measured by the value of the utility lost because of defoliation or killing of trees multiplied by the number of people suffering this loss. However, the valuation of this loss will vary from individual to individual, and to segregate between those who incur some loss and those that incur no loss is impossible. By making some simplifying assumptions, though, a maximum value of the benefit can be derived.

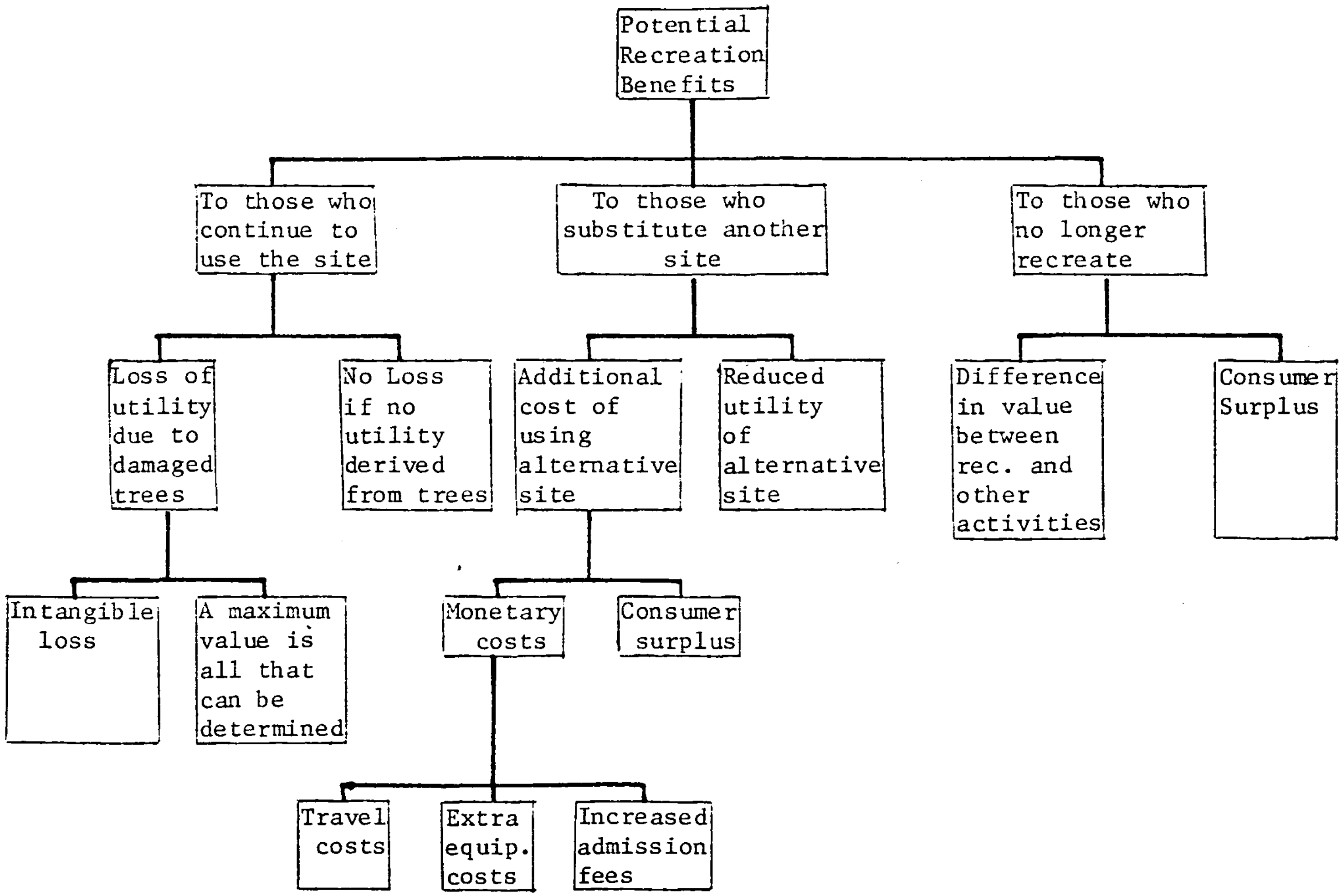


Figure 10. Potential Recreation Benefits

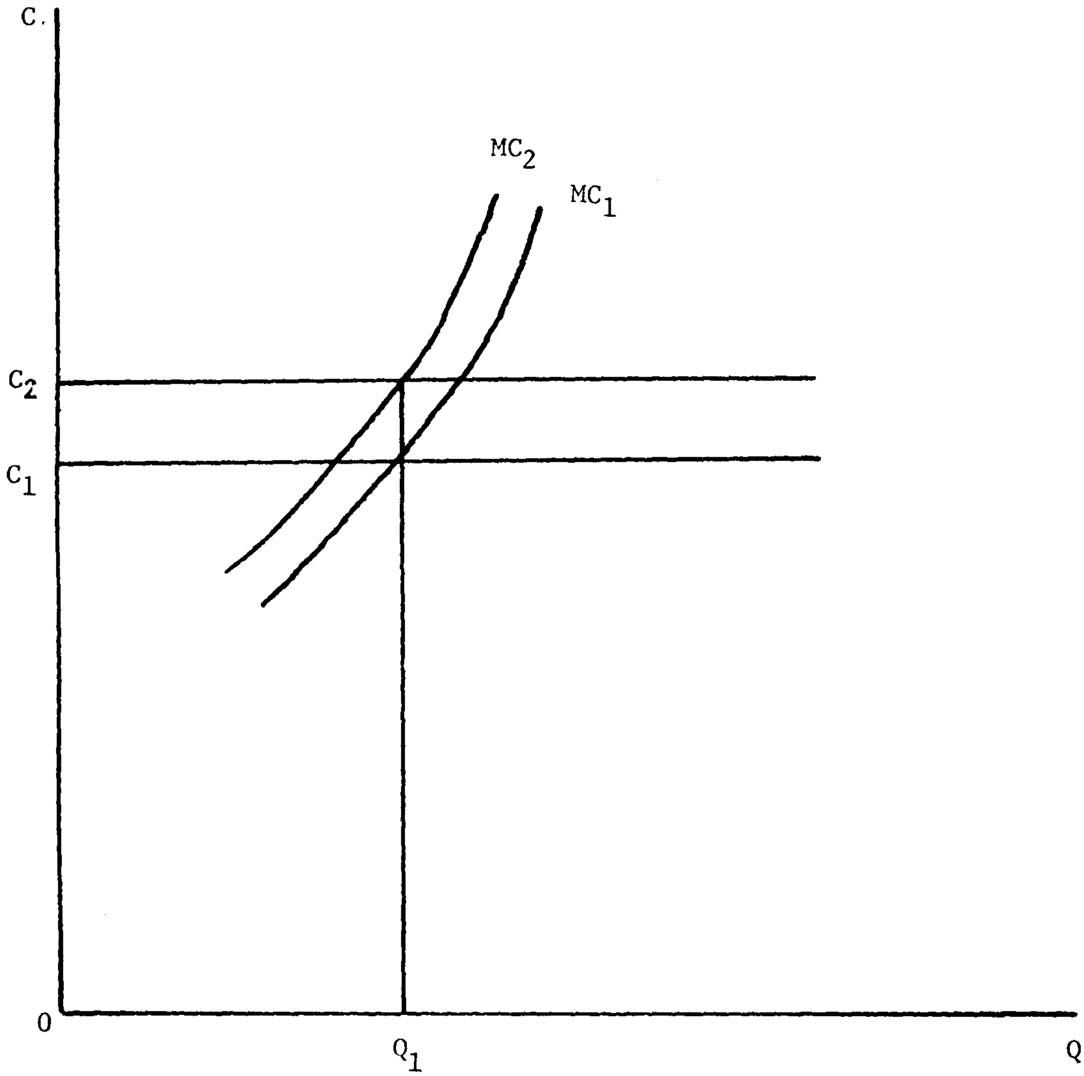
Looking at figure 11, and assuming that there is only one price (price = marginal cost) for all alternative sties and that the only difference between the primary and alternative sites is the insect damage, the potential benefit to those who continue to use the infested site must be less than C2-C1 per person. This is so because, if the utility cost at an infested recreation site was equal to or greater than the marginal cost of switching to the uninfested site, the people would switch. Since they did not, the cost, or potential benefit, can be assumed to be less than the marginal cost of using the alternative sites.

As a final note, it is suspected that this cost will not have any significant effect on the analysis. Therefore, recognition that these costs exist may be all of the effort that can be justified in quantifying the potential benefit.

Substitution of an Alternative Recreation Site

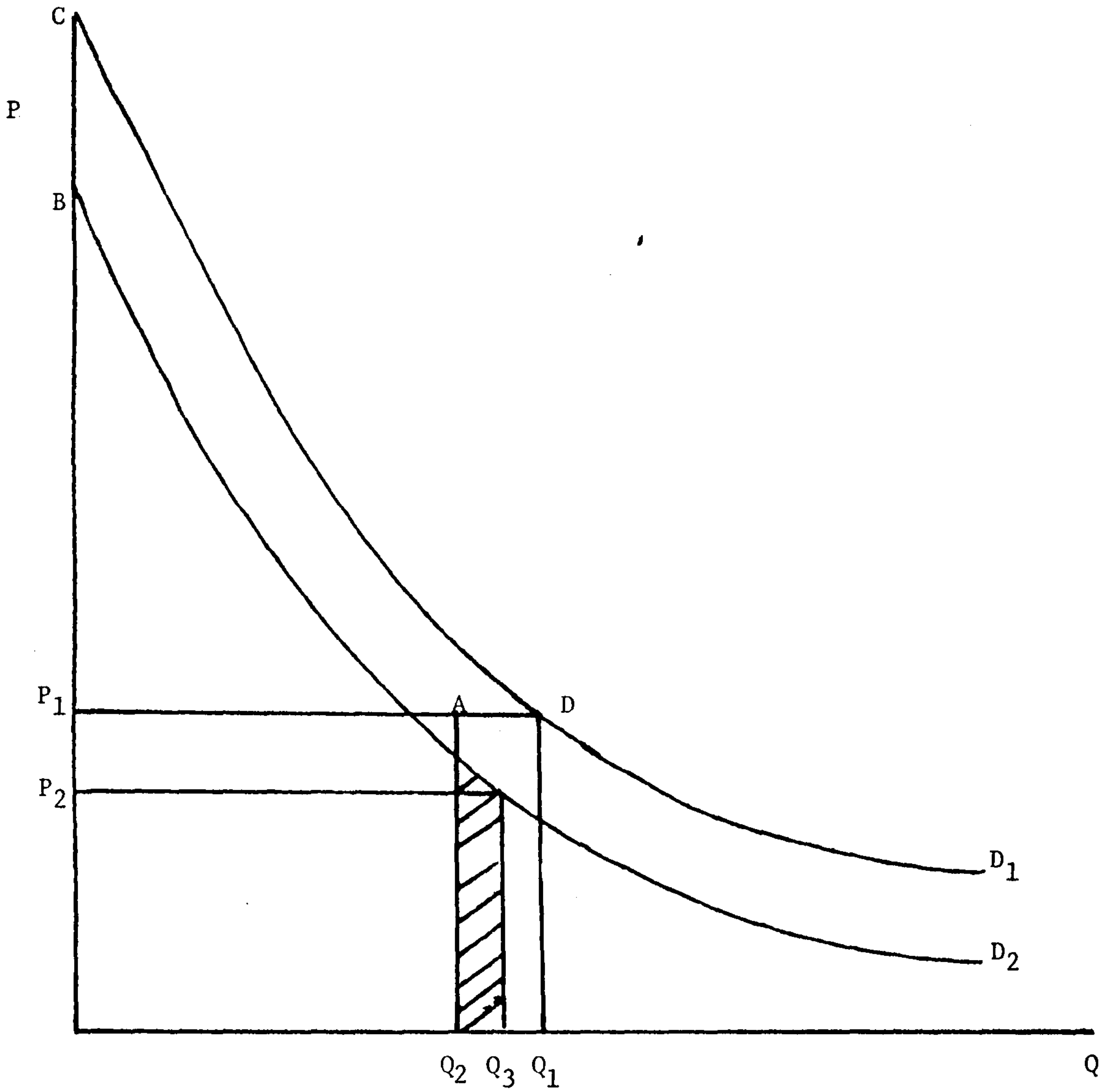
If the alternative site or sites differ from the original site only by the insect damage the measurement of the potential benefits is straightforward.

In figure 12 D_1 is the demand for the original, unattacked site and D_2 is the demand for the alternative site. If the alternative site has the same price, P_1, as the original site, the quantity taken will shift from Q_1 to Q_2. The potential benefit is the value of the change in quantity taken (Q_2,A,D,Q_1) plus the change in consumer's surplus (A,B, C,D).



MC_1 = marginal cost of recreating at infested site
MC_2 = marginal cost of recreating at alternative site
P_1 = cost of using infested recreation site
P_2 = cost of using alternative recreation site
Q = quantity of recreation

Figure 11. Estimating maximum loss to continued users of insect infested sites



D_1 = demand for original site
D_2 = demand for alternative site
P_1 = price of original site
P_2 = price of alternative site
Q = quantity of recreation taken

Figure 12. Social cost of moving to alternative recreation sites

However, the price of the alternative recreation site may not be the same as the price of the original site. In figure 12, if the price of the alternative site is P_2, the quantity taken will move from Q_1 to Q_3. The potential benefit is the same as in the preceding paragraph minus the shaded area in figure 12.

Discontinuing Recreation Activities

Discontinuing recreation activities implies one of two things. Either the cost of using the primary site is greater than the benefits derived, and there is no alternative site, or the costs outweigh the benefits on both the primary and alternative sites.

In the first instance, he has no choice but to move from a more preferred to a less preferred (non-recreation) activity. This moement implies a shift to a demand schedule to the left of his demand for the non-infested primary recreation site, and the potential benefits of pest control to him are measured in the same way as the potential benefits to users of alternative recreation sites (figure 12). The benefit is the market value of the foregone recreation activity plus the consumer surplus for this activity, minus the market value of the alternative activity plus its consumer surplus.

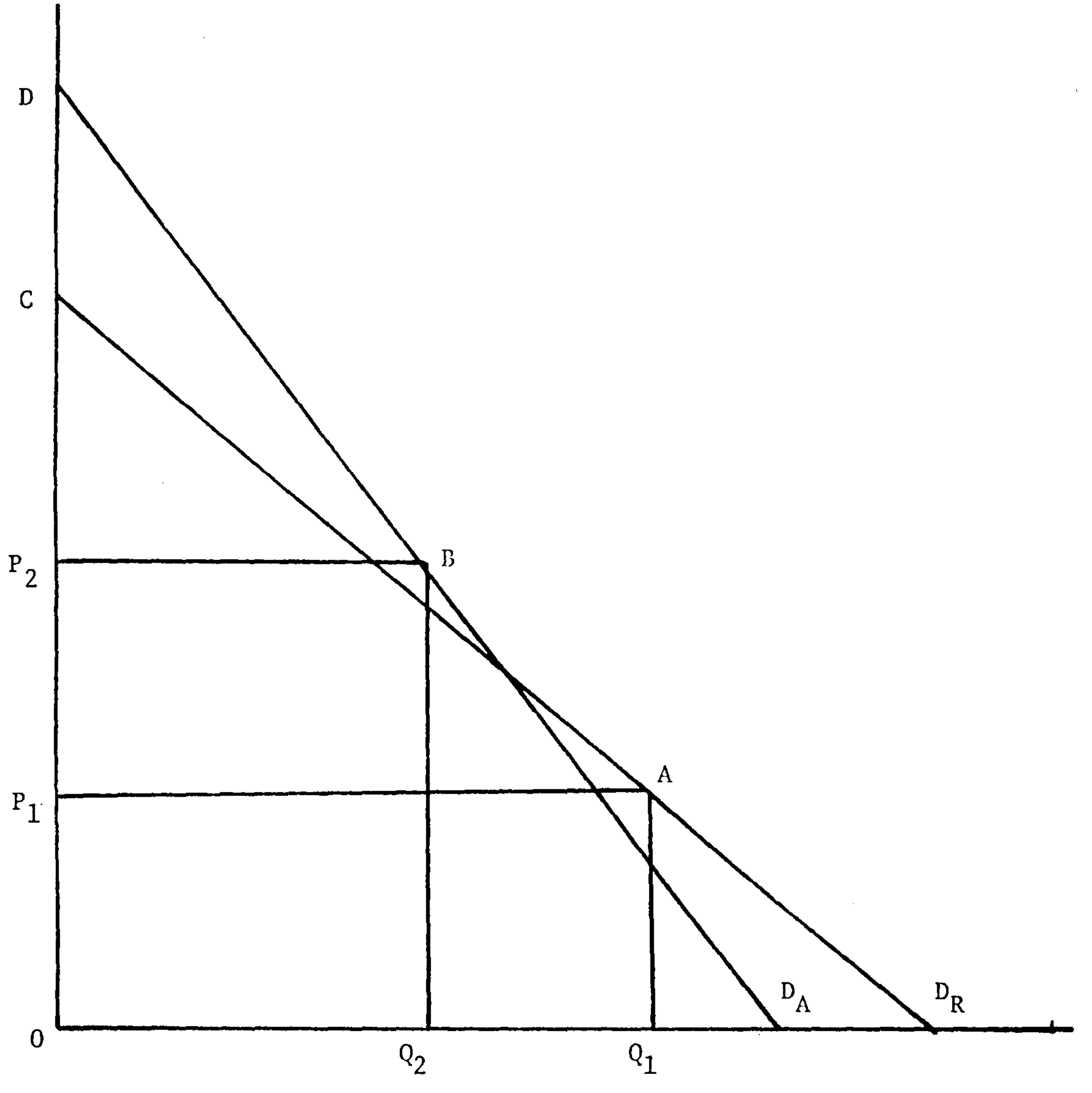
Although this will give the potential benefit, given the innumerable alternative activities open to those who no longer recreate, it is unlikely that any aggregate or individual demand curves can be derived for these activities. If these benefits cannot be quantified it must be recognized that the analysis under states total benefits by this amount.

In the second instance, where the consumer is not willing to pay for the alternative recreation site or use the insect damaged primary site, a situation exists as illustrated in figure 13. This is similar to the case of choosing an alternative recreation site, except that another demand schedule enters the picture at price level P2, because the marginal return is greater for this new activity than for recreation of the type provided at the infested site. Thus, the potential social benefit is again the market value plus the consumers surplus of the primary recreation site minus the market value plus the consumer surplus of the alternative activity. This figure will always be positive. Were it not, the consumer actually prefers the alternative activity and would have moved there regardless of any insect activity. Therefore, the consumer would realize no benefit from controlling the insect.

In Summary

The three types of response to insect attack on recreation area use as outlined by Leuschner and Newton (8) have been discussed. To measure the potential benefits associated with these responses one needs to know the market price for the undamaged recreation site, the market price of all alternatives, the consumer demand curve for the primary and alternative activities and the proportion of the total recreation population affected that responds in each of the three ways.

Unfortunately, quantifying this data, especially the intangible benefits, is often impossible or infeasible. In this event, that which can be quantified should be, and a note made that the total benefits are understated by the value of the rest.



P_1 = price of primary recreation activity
P_2 = price of alternative recreation activity
D_R = demand for primary recreation activity
D_A = demand for alternative recreation activity

Figure 13. Potential benefits to people unwilling to pay the price of alternative recreation sites

Esthetic Benefits

The potential esthetic benefits of a pest control program are illustrated in figure 14. Although they are considered separately here, they are implicitly included in recreation benefits. When doing an analysis, if the esthetic benefits are included in recreation benefits it would be double counting to include them again as a separate category of benefits.

Benefits to Direct Users of the Forest

Direct users are those people whose activities carry them into the forest, such as hikers or picnickers. In figure 14 their potential benefits are divided into the same three response categories as the recreation benefits. As one would logically expect, the potential benefits to direct users are calculated in the same manner as recreation benefits.

Benefits to Indirect Users of the Forest

Indirect users are those that only derive benefit from the forest at a distance, such as pleasure drivers. Again, these benefits are calculated the same way as recreation benefits are.

As a note of caution, the analyst must be careful not to calculate benefits when they don't exist. For instance, if an infestation is not visible from the road, there can be no benefits to the pleasure drivers derived from the control of these infestation spots.

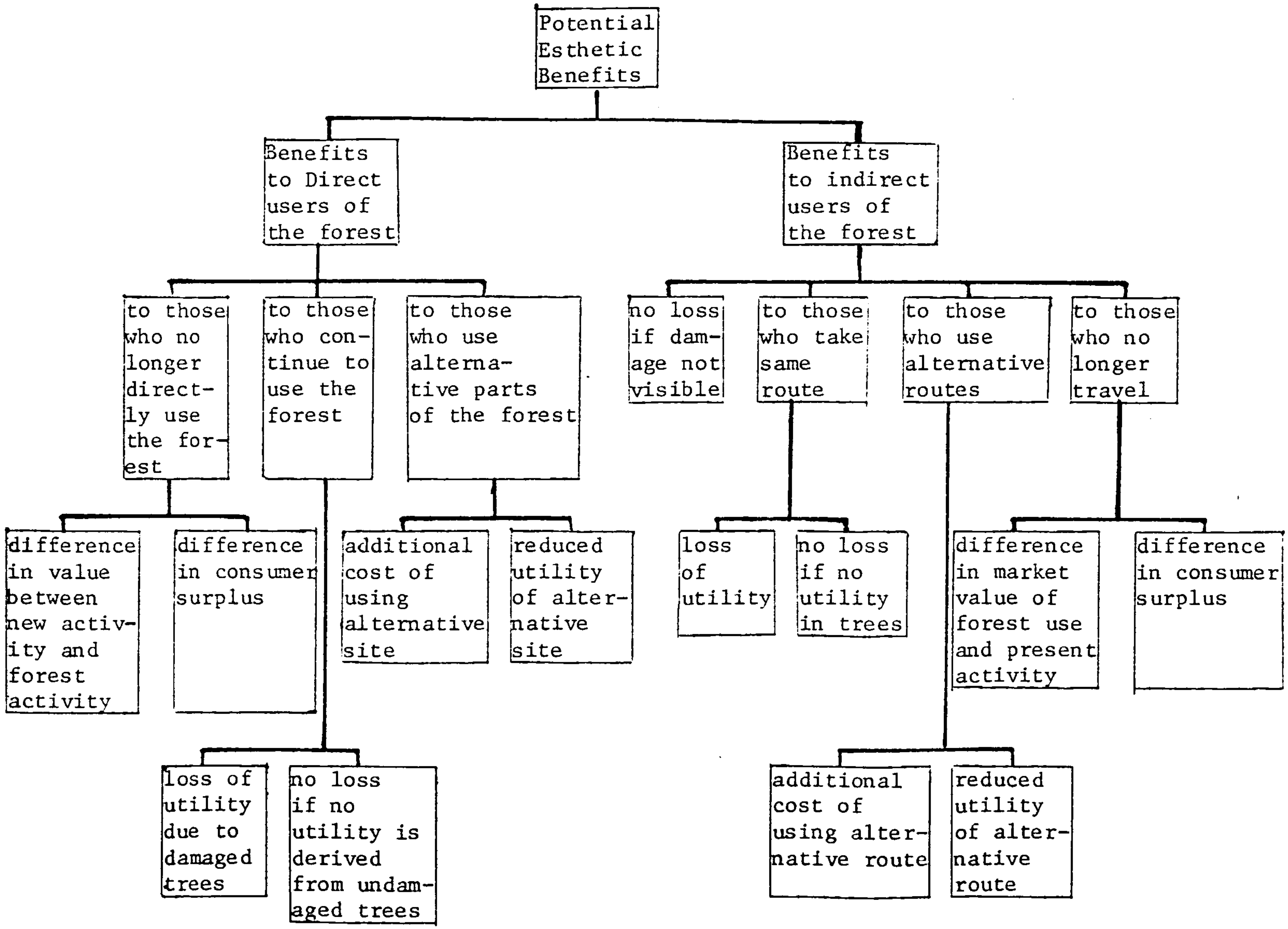


Figure 14. Potential esthetic benefits

Watershed Benefits

Again, using the categories outlined by Leuschner and Newton (8), there are three possible sources of watershed benefits (figure 15). These are; changes in erosion levels, changes in the timing of water release, and changes in the volume of water released.

Changes in Erosion Levels

Elimination of erosion is a watershed benefit when stream sedimentation occurs. Pest control action may cause increased erosion becoming a negative benefit but in this paper we will proceed as if a program reduced erosion to eliminate redundancy in outlining techniques. Should the watershed benefits be negative in a particular case, the method of identifying and measuring the changes would be identical. The results, however, would be added as a cost rather than a benefit.

There are four potential benefit areas associated with the reduction of soil erosion.

Decreased flood damage - Flood damage may be decreased because sedimentation is not filling the stream or lake beds, thus giving these water courses more holding capacity. With the higher holding capacity flood stages would not be reached as quickly as if the sediment were present.

Conceptually, the measurement of this potential benefit is uncomplicated. It is the market value plus the consumers surplus of the physical damage prevented, plus the value of the intangibles, such as the lives saved or freedom from worry of floods.

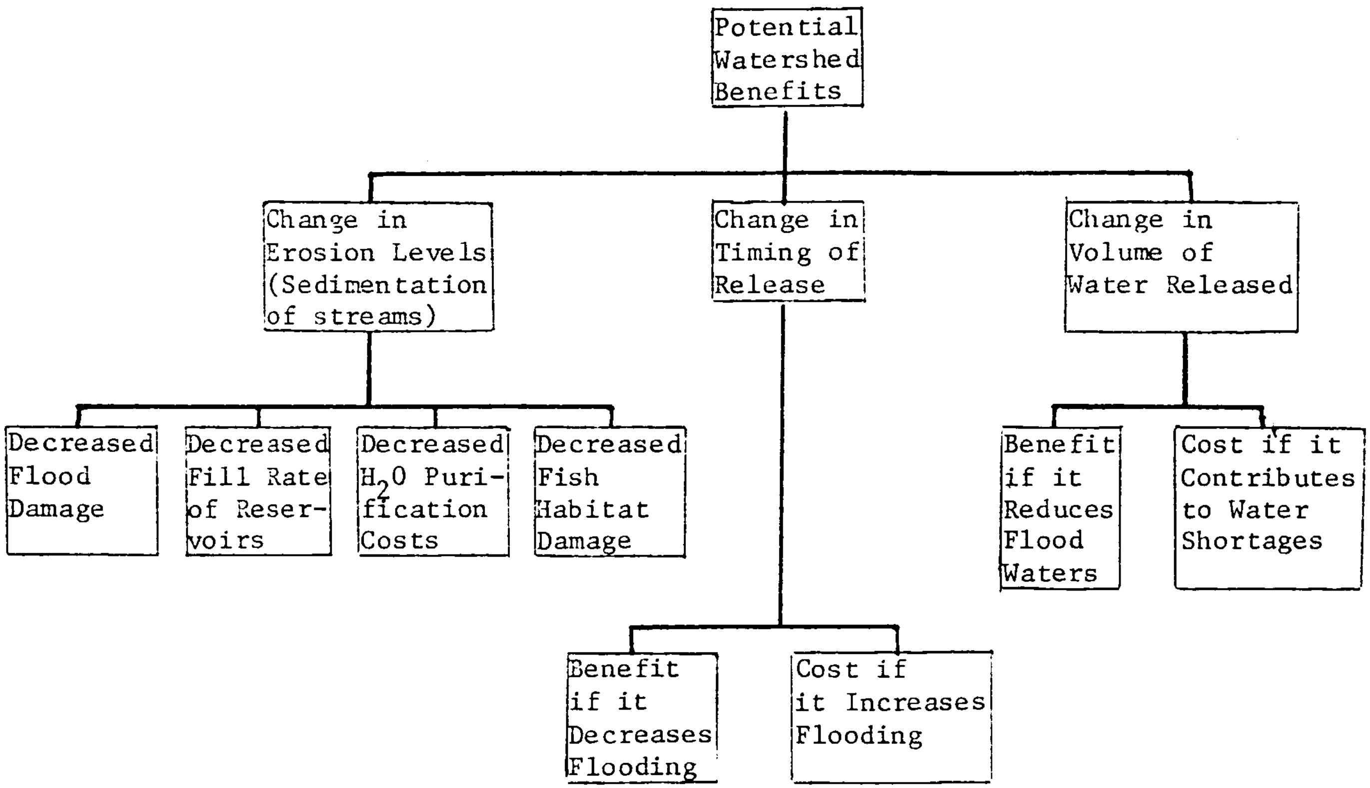


Figure 15. Potential watershed benefits

In practice, though, their measurement is complicated for three reasons. First, the benefits are likely to be so diversified and dispersed that to identify even a large portion of them may be impossible. Second, insect damage to forested areas will not be the only causal agent in flooding, and to determine what share of the flooding is a direct result of the insect attack will be difficult. Third, the valuation of intangibles, as always, is never easy.

However, in many cases, especially in the eastern United States, insect attacks will not have a significant impact on the level of flooding due to erosion. Only in areas where soil stability is extremely sensitive to cover stability and massive foliage devastation has occurred could there possibly be a measurable effect.

Reduce the fill rate of reservoirs - Measuring of this benefit depends on how seiment buildup in reservoirs is handled. If the sediment is removed by dredging, the potential benefit is the present value of the cost of all anticipated dredgings caused by insect related sedimentation. If, instead of dredging, the reservoir is abandoned before its projected life is over, the present value of the foregone benefits of the reservoir is the potential benefit of the insect control program. To calculate these benefits the closing date of the reservoir and the number of years this date was pushed forward as a result of insect related sedimentation. Next the value of the benefits foregone is calculated in the same manner as discussed in the section on recreation benefits. However, continued use benefits would not be a factor since the reservoir is abandoned. Finally, these values are discounted, to the present, using the social discount rate, to calculate the net social benefits.

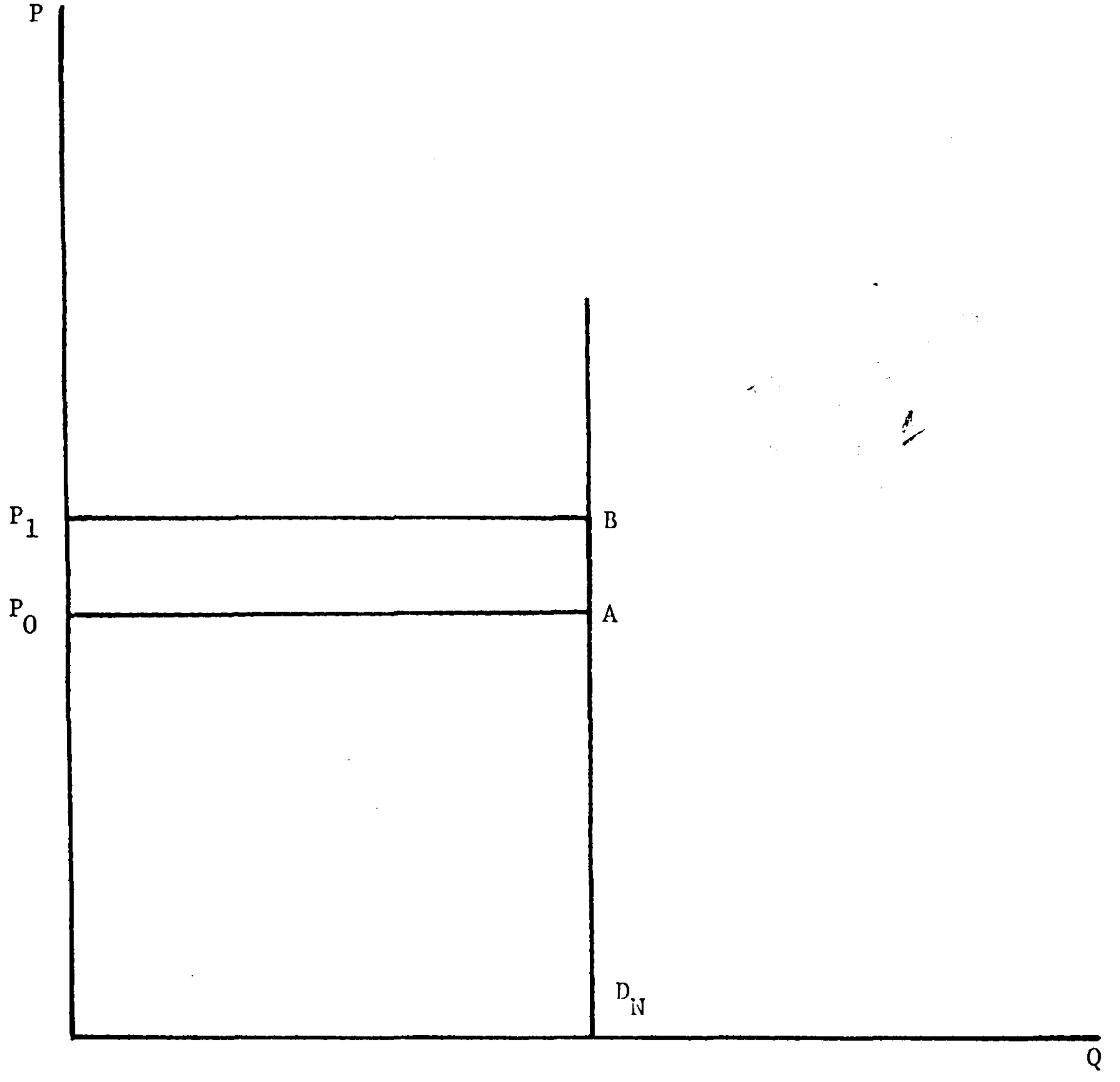
As with the potential flood damage reduction, forest insect damage will only be one of the factors associated with the sedimentation of a reservoir, and determining how much is due to insect damage will be difficult. Also, except in rare instances, it is hard to visualize a forest insect attack having a significant impact on the sediment fill rate of a reservoir.

Decrease in water purification costs - The potential benefits here are measured by the excess costs of water purification multiplied by the volume of water purified. It is doubtful that there would be any consumer surplus benefits given the almost unit elasticity of demand for water over any meaningful range of prices. This is illustrated in figure 16. At either price level, P0, or P1, the consumer surplus is virtually infinite, so the only difference, or benefit, is measured by the difference in the market value of water with or without insect related sedimentation (P0,P1,B,A).

Again, as with the two previous benefits, determining the proportion of purification costs relating to insect damaged forests will be difficult. In addition, the impact of this factor is probably small.

Changes in aquatic life - Included here would be both changes in numbers and types of aquatic, primarily fish. This change would come about through changes in habitat.

For commercial species, the potential benefit is measured by the market value of the reduced number of fish caught plus the consumer surplus.



P_1 = price of purifying water with insect related sedimentation
P_0 = price of purifying water without insect related sedimentation
D_N = demand for purified water

Figure 16. Potential water purification cost reductions

For sport or recreation species, the potential benefit is measured by the reduced value of the fishing experience caused by sedimentation. Procedures for measuring this value are outlined by Clawson and Knetsch (2).

Again, forest insect related sedimentation will be only one of the factors effecting aquatic populations, and its impact will generally be small.

Changes in the Timing of Release

The potential benefit is the reduction of flood damage that results from reducing the amount of water released from insect infested forest lands at peak flow periods.

This benefit is measured by adding the market value of the reduced damage to its consumer surplus. All of the valuation and impact factors that apply to changes in erosion levels apply here also.

This is the area that probably has the highest likelihood of producing negative benefits. Negative benefits would occur, of course, if the insect damage were to alter the timing of release so as to add water to the peak flow periods.

Changes in the Volume of Water Released

These benefits are analagous to those associated with the timing of release, except the quantity rather than the timing of release of the water is being considered.

To assess all three of these effects - erosion, timing, and volume - runoff volume and timing measurements need to be taken at the forest and compared to total volumes of water and sedimentation in affected water courses. In this manner, some idea of the physical impact of forest insect damage on watersheds can be derived. Next, the physical damage can be valued to arrive at a potential benefit of controlling the insects.

Soil Benefits

Potential soil benefits are the difference in value of the timber stand before and after soil damage as a result of the insect attack. Changes in the value of the timber stand can come about in one of two ways, as illustrated in figure 17.

First, if soil is lost by erosion or is in some other way reduced in quality, less desirable species composition and/or growth rates may occur in the subsequent stand. Elimination of these undesirable stand characteristics is the potential benefit. It is measured by subtracting the present net worth of the stand after soil damage has occurred from the present net worth of the stand had the soil damage not occurred.

Second, if an entire stand is not killed, there may be reduced growth on the residual stand. The potential benefit here is measured in the same way as the reduced growth on surviving trees discussed in the section on timber benefits.

Fortunately for the analyst, these benefits are implicitly included in the timber benefits discussed at the beginning of this section. To try and segregate soil benefits from the timber benefits would be an interesting intellectual exercise, but would be of doubtful purpose in conducting a benefit-cost analysis.

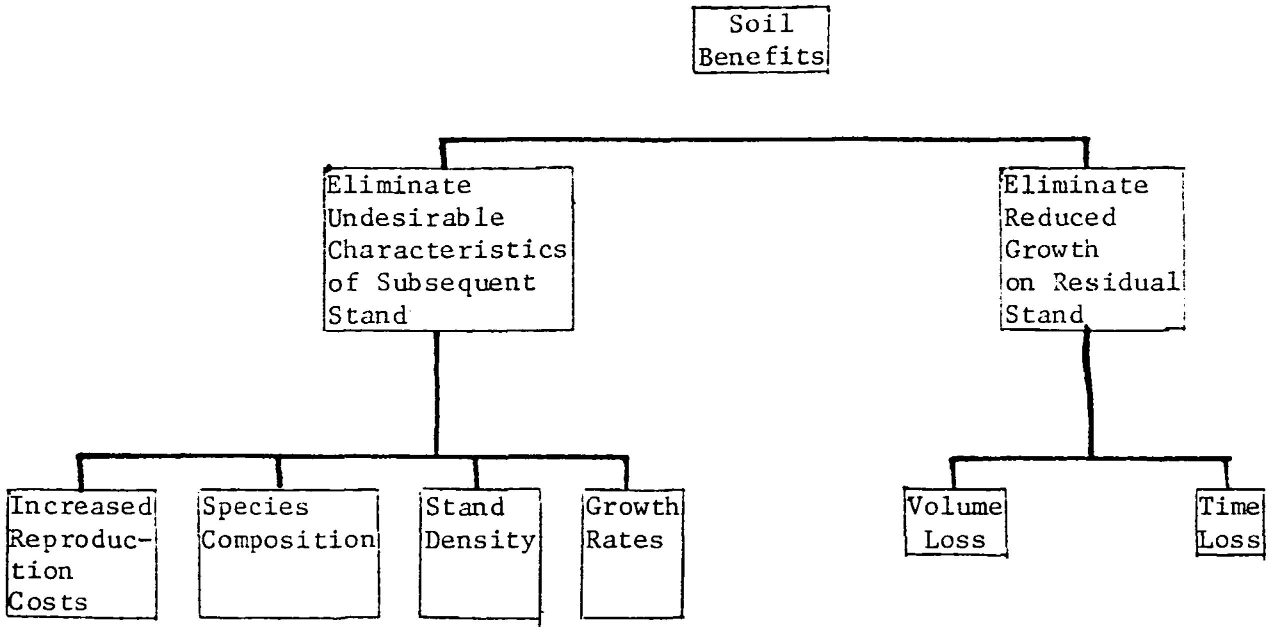


Figure 17. Potential soil benefits

Wildlife Benefits

Just as watershed benefits may be positive or negative, so wildlife benefits can be positive or negative. Here, again, we will assume positive benefits accrue to a pest control program, with the understanding that negative benefits are identified and measured in the same fashion as positive ones. The three wildlife benefits - bird and mammal, fish, and plant and insect - are outlined in figure 18. The loss in each of these categories is a result of the loss of habitat due to the presence of the insects. That is, the insects do not destroy the wildlife directly (plants possibly excepted), but the insects may alter the habitat to the degree that some species are reduced or eliminated.

Potential benefits for each of the categories can accrue to both commercial and sport species. The potential benefits for commercial species is measured by the market value of the volume of meat, fish, etc. saved plus the consumers surplus. For sport species, the potential benefits are the value of the recreation experiences lost due to reduced numbers of wildlife. The measurement technique for calculating this benefit would be the same as outlined in the section on recreation benefits.

There always exists the possibility that the habitat changes that reduced the numbers of one species will increase the numbers of another species. If this occurs, the value of the new species is calculated in the same manner as the value of the decimated species. A net benefit is obtained by subtracting the value of the new species from the value of the eliminated ones.

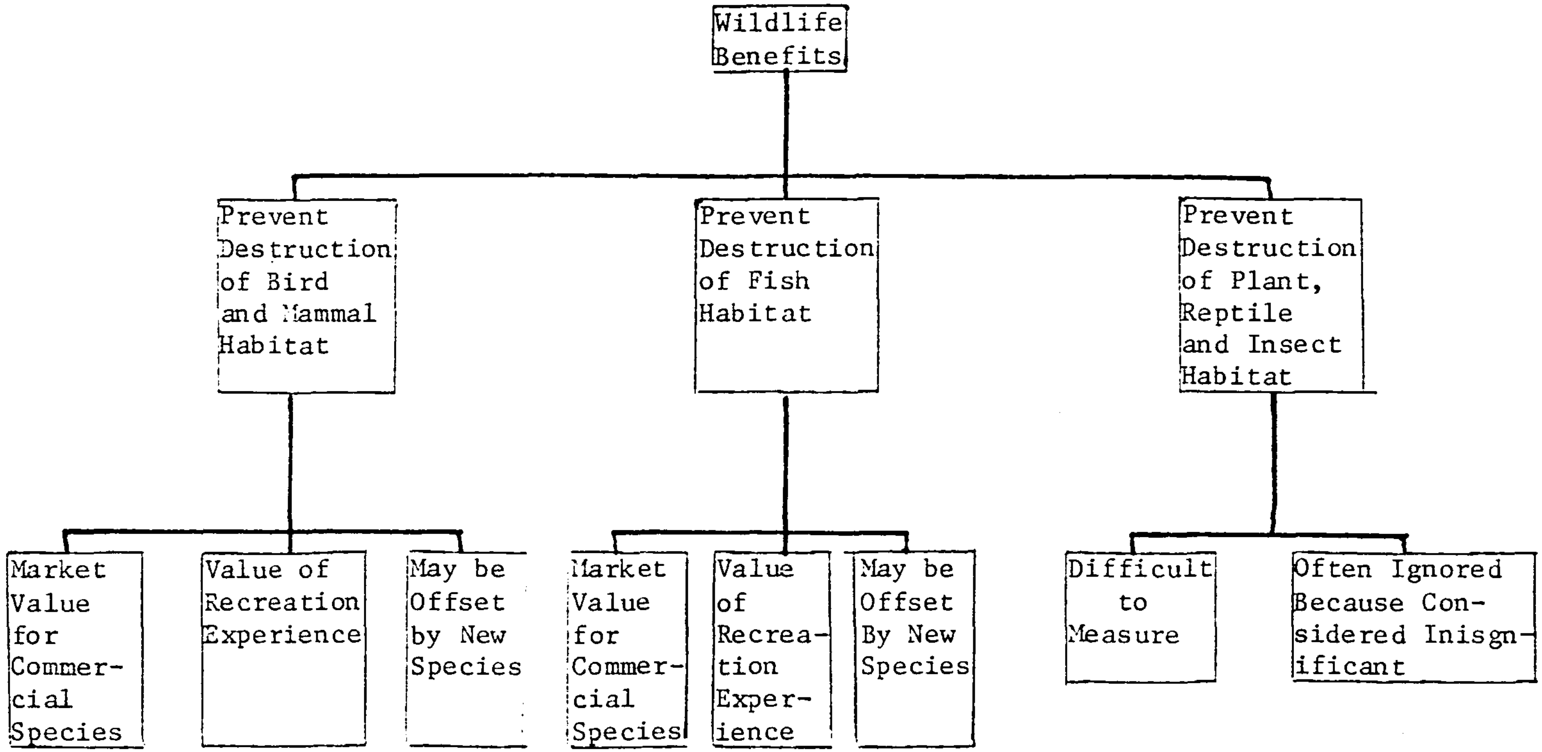


Figure 18. Potential wildlife benefits

As a word of caution, if the benefits associated with fish have been calculated along with the watershed benefits, it would be double counting to also include them in the wildlife benefits.

Grazing Benefits

In some parts of the country livestock is grazed under forest stands. Generally, one would not think of positive grazing benefits being associated with pest control programs (figure 19), unless a stand is destroyed and thick reproduction prevents grazing. In this case the benefit is measured by the dollar value of decreased live-stock per acre that are grazed multiplied by the number of acres effected.

If the insect attack opens up the stand to greater forage growth, there could be a negative benefit of pest control, but only if the land was kept in timber. As pointed out by Leuschner and Newton (8), if a destroyed stand is converted to pasture there is no benefit to control at all. This is because the conversion to pasture implies that timber was not the best use for the land, and it would have eventually been converted to pasture regardless of the insect.

Summary

The social benefits of a forest insect control program will usually occur in one of the seven areas mentioned by Leuschner and Newton (8). However, there may be some overlapping from one area to the other, so the analysist must be careful to avoid double counting.

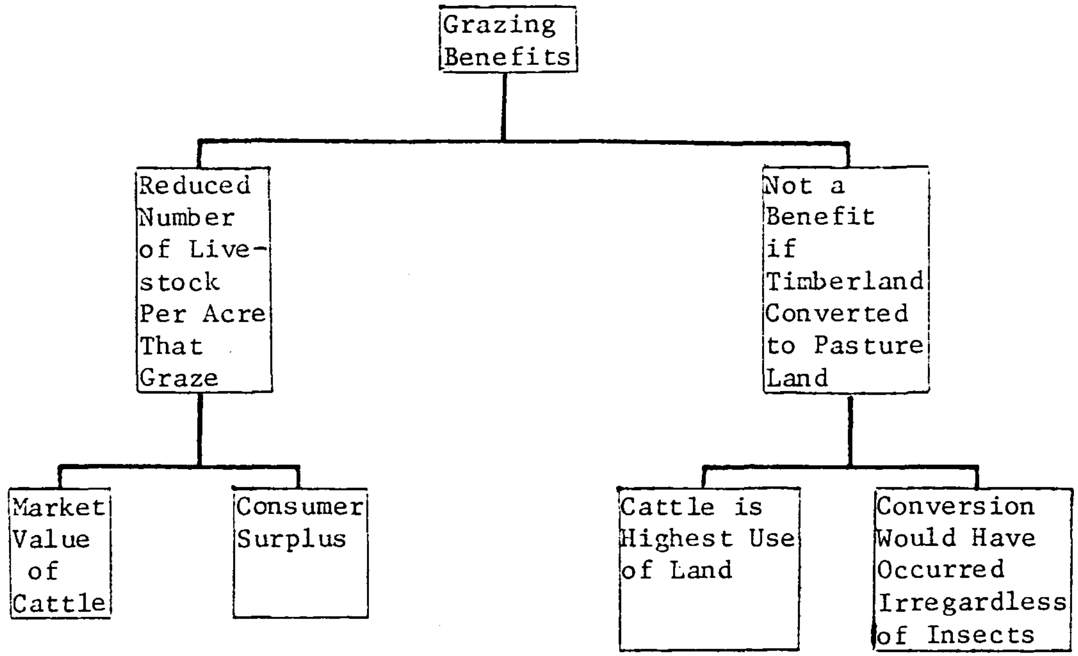


Figure 19. Potential grazing benefits

In addition, it is important that the planning horizon and the discount rate be the same for both costs and benefits, so that the analysis will be meaningful. This not to say that the planning horizon cannot go on beyond the last year in which one or the other occurs. It only means that the same time span must be examined for both costs and benefits.

Finally, intangibles will usually play a much larger role in the measurement of benefits than of costs. Often times it will be impossible to measure these benefits. However, they must not be ignored. If the analyst cannot come up with a good estimate for these benefits he must at least recognize them and let the decision makers place a weight on their importance.

RESULTS

After the identification and measurement of all benefits and costs have been completed, the present net worth of each is found and the costs are subtracted from the benefits to arrive at a net social value of the forest insect control program.

Present Net Worth vs. Internal Rate of Return

Dasgupta and Pearce (3) point out that some people have preferred to use the internal rate of return to calculate the net social value of a program on the grounds that decision makers are more comfortable with a rate of return. However, they go on to point out four reasons why present net worth is preferred to internal rate of return for calculating the value of social programs.

Sensitivity to economic life - The internal rate of return tends to favor projects with shorter planning horizons, as well as being biased against large capital outlays. Therefore, when projects with different planning horizons or different capital costs are being considered the internal rate of return may not indicate the project with the highest social value as the best project.

Sensitivity to time-phasing of benefits - The internal rate of return tends to favor projects that have an even flow of benefits or that have a high percentage of benefits early in the project, even though the present net worth of the projects are lower than for other projects.

Mutually exclusive projects - When considering mutually exclusive projects the internal rate of return is biased toward low cost projects. Dasgupta and Pearce (3) point out that a second rule, the "rate of return over cost" rule, must be applied in addition to internal rate of return calculations to arrive at the correct answer.

This rule says that when considering two mutually exclusive projects with different capital requirements, the higher cost project should be chosen only if two criteria are met.

First, the IRR must be higher than the guiding rate of interest and, second, the marginal return on the additional capital required for the more expensive project must be higher than the guiding rate. If these two conditions are satisfied, the higher cost project should be chosen.

Multiple Roots - The internal rate of return is the solution to a polynomial equation, therefore, it can give more than one answer. This is totally unacceptable, especially if the answers fall on both sides of the guiding rate.

Decision Criterion

Completing a benefit-cost analysis on a forest insect control program will indicate its feasibility but not its desirability. The desirability of a forest insect control program will usually be decided under one of two conditions.

In the first instance it will be compared with other (usually mutually exclusive) forest insect control programs. For instance, the U. S. Forest Service may decide to initiate an intensive control program for southern pine beetle (D. frontalis Zimm) in the southeast. After the decision has been made on the maximum that can be spent and the guiding rate of return that will be used, the decision process is rather straightforward. Assuming all other factors equal, rank all programs, whose cost does not exceed the maximum and whose return at least equals the guiding rate, according to their level of net benefits. The project with the highest level of net benefits would then be chosen as the most desirable.

In the second instance it will be compared to complementary or unrelated projects which are not mutually exclusive. Assuming you are still operating under a budget constraint, projects should be ranked according to their benefit-cost ratios and projects chosen from the highest ratio on down until the budget is expeded. Table 1, borrowed from Dasgupta and Pearce (3), will illustrate why.

Assuming a budget of $100, project X would be chosen if the highest net return were the decision criteria, with a net return of $100. But, using benefit-cost ratios, projects Y and Z would be chosen, with a total net return of $130.

The implications of this example are very important in that it shows the desirability of considering alternative plans of action and of supplying decision makers with as much information as possible.

For example, suppose the U. S. Forest Service has $100 of uncommitted capital in its budget. Further suppose that project X is a proposed forest management incentive program, project Y is a pest control project and project Z is a reforestation program. Had the Forest Service analysts submitted only the information on project X to the Forest Service decision makers because, by using total net benefits as the evaluating standard, project X was clearly the best, society would not receive maximum possible benefits. Had all information been supplied to the decision makers, and the benefit-cost ratio used as the decision criteria, society would receive $130 rather than $100 worth of benefits.

Therefore, in choosing a decision criteria for evaluating proposed projects three things must be kept in mind. What is the budget ceiling for capital expenditures? What is the guiding rate? Are you trying to get the highest net benefits from a particular type of project or trying to get the highest net benefits from a specified level of investments?

Table 1. Benefit-cost ratios from Dasgupta and Pearce (3)

PROJECT	COST	BENEFITS	(B-K)	B/K
X	100	200	100	2.0
Y	50	110	60	2.2
Z	50	120	70	2.4

DISCUSSION

Advantages of Benefit-Cost Analysis

Benefit-cost analysis is particularly useful for analyzing projects undertaken by and/or for the public because it attempts to take into account non-priced benefits and costs that are ignored by traditional demand analysis and production economics. Admittedly, many of these benefits and costs are impossible to measure. However, some of them can be measured, which moves us one step closer to finding the true social value of any project or program, and by recognizing the existence of those that cannot be measured benefit cost analysis provides vital information to decision makers. By identifying these unmeasured benefits and costs the analyst makes the decision makers cognizant of their existence and identifies for him what goods and services require subjective valuation.

In addition, benefit-cost analysis distinguished between transfer payments among individuals in society and actual benefits of and costs to society associated with a program. This helps to keep the benefits of a program from being erroneously inflated by passing the same dollar around to several individuals.

Finally, from a pragmatic point of view, benefit-cost analysis would have to be recommended as the method for analyzing public investments because no better method has been developed to date.

Disadvantages of Benefit-Cost Analysis

While b3nefit-cost analysis is the best analytical tool available for evaluating public investments, it does have its drawbacks.

First, it can be a very costly form of analysis, especially in projects where costs or benefits are diversified and intermingled with other costs and benefits. If one is not careful, the cost of an analysis may soon become prohibitive. It is for this reason that sensitivity analysis can be used to such advantage in determining if additional benefit or cost information is worth the price of obtaining it.

Second, benefit-cost analysis does not consider the distribution of costs or benefits associated with a program. Thus, it could be hard to justify a program whose benefits were enjoyed by upper-middle class suburbanites while the costs were borne by ghetto dwellers - even if it did have the highest benefit-cost ratio of all projects considered. Therefore, even after an analysis is completed, a critical look must still be taken at the income distribution effects of a project.

Third, many times the feasibility, not to mention the desirability, of a project relies on the somewhat arbitrary valuation of intangible costs or benefits. Obviously, this can leave the results of an analysis open to much honest disagreement, not to mention the possibility of using the tool for purposes it was never intended.

Conclusion

Before jumping headlong into detailed benefit-cost analyses of public investments, pilot estimates should be made of expected returns from investments in order to set limits on how much to spend on an analysis.

Then, even if pilot studies indicate detailed analyses are feasible, decision makers should realize that, besides the fact that economic analysis will not answer all of the pertinent questions surrounding public decisions, benefit-cost analysis is not even a perfected tool for answering the economic questions. Therefore, benefit-cost analysis can be a good decision making aid, but it should never be used as the sole decision making criterion.

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BENEFIT-COST ANALYSIS

AS APPLIED TO

INSECT PEST CONTROL PROGRAMS

Ronald B. Neal

ABSTRACT

A benefit-cost outline designed to evaluate the social value of on-going and proposed forest insect control programs is presented.

Chapter two briefly discusses some economic concepts used in benefit-cost analysis. Those discussed are: consumer's surplus, social discount rate, shadow prices, characteristics of social costs, characteristics of social benefits, external effects, and risk and uncertainty.

Chapters three and four discuss, respectively, the identification and measurement of social costs and benefits.

Chapter five discusses the relative merits of using present net worth and the internal rate of return in evaluating pest control programs. It also discusses decision criteria under different circumstances.

Finally, in chapter six, the advantages and disadvantages of benefit-cost analysis are discussed.