Staff Papers Series

Staff Paper P88-24

August 1988

THE ECONOMICS OF WATERSHED MANAGEMENT

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Paper presented at the seminar on
water resources and water quality management
held in Amman, Jordan, May 28-June 2, 1988.

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by K. William Easter[1]

The major concerns in watershed management are twofold. First, how can we keep the soil from moving to places we do not want it, and second, how can we make better use of the water that falls in the watershed? The first concern leads us to consider a wide range of activities which provide better soil cover and reduce soil loss. The second concern can also lead to soil protection activities but can involve water harvesting practices. In watershed management, we are dealing with two of the key natural resources, soil and water, and how people interact with these resources.

Considering these two important resources within the context of a watershed has a strong economic logic. The watershed is a better analytical unit in which to evaluate soil and water management strategies than is the farm unit or most political units. This follows from the flow of water and the fact that activities in one section of a watershed can have an effect in others, some distance away and usually downstream. In other words, there are important interrelationships in a watershed that must be taken into account when managing the land and water resources.

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[1]K. William Easter, Professor of Agricultural and Applied Economics, University of Minnesota. This paper draws heavily on the chapter John Dixon and I did on economic analysis for our book, "Watershed Resources Management: an Integrated Framework with Studies from Asia and the Pacific", published in 1986 by Westview Press.

The author would like to thank Craig Cox and Charles Rodgers for their help and comments on an earlier draft.

"Externality" is the concept in economics which encompasses these interrelationships. It is defined as the unintended effect (negative or positive) of an action upon a third party that is not reflected in the market (Easter and Waelti, 1980). A classic example involves silt accumulation in a reservoir, caused by soil erosion in an upstream area where a road has been constructed for timber harvesting. The externality, siltation, is the unintended effect of the road construction that damages those using the reservoir, but not the road builders or those harvesting the timber. A positive externality could be created for the same reservoir with a program to improve grazing in upstream areas. The improved grazing would provide better ground cover and reduce soil erosion and siltation rates.

If one uses the watershed as the decision unit, this will internalize these externalities. For example, when the road is built, the costs imposed down stream by the silt will have to be counted. Consequently, the road may have to be built in a manner that minimizes the soil erosion it creates. The road will be more expensive to build but downstream costs (damages) will, very likely, be reduced more than the road buiding cost will be increased. Thus maximum net social benefits can be attained only when off-site damages caused by road construction are included as part of the costs of roads.

For many resource decisions, the watershed is an appropriate unit for economic welfare analysis. It internalizes most externalities within its boundaries. Economic analysis based on the watershed unit will include many of the important costs and benefits caused by activities involving use of natural resources.

The major problem one encounters with the watershed unit is that political boundaries generally cut across watersheds. For example, activities in Nepal will affect watersheds in India and Bangladesh. Since these are completely separate political units, it is very difficult or even impossible to manage, as one unit, the watersheds which start in Nepal but extend into India and Bangladesh. Difficulties arise even within a country when watersheds cut across several local or state political units. However, some of these problems could be solved by creating special watershed districts.

One of the few examples where the watershed units corresponded with the political units was in ancient Hawaii (Easter, Dixon and Hufschmidt, 1986). This conjunction between political, economic and physical resource boundaries appears to have served the Hawaiians very well. Although it may be difficult to duplicate in today's complex world, their success in watershed management indicates what is possible. One should not, without careful analysis, construct projects or encourage activities that knowingly violate good watershed management practices.

FRAMEWORK FOR ECONOMIC ANALYSIS

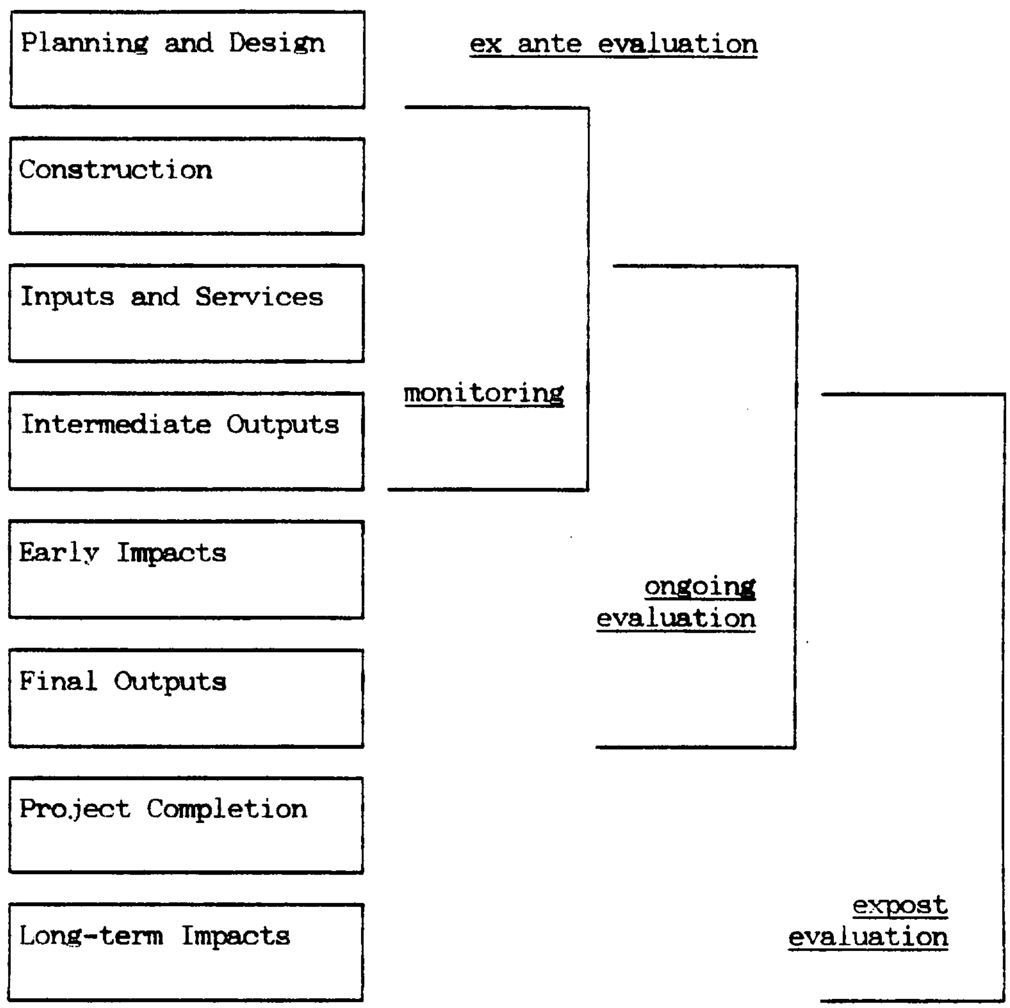
The basic reason for economic analysis is that there usually are limited resources (money, time and technical and management skills) and one would like to use fewer resources rather than more to accomplish the same objective or objectives. First, one wants to be sure that the proposed action is going to produce more benefits than it costs. Second, does it offer the highest net returns of all feasible alternatives?

Economic analysis is usually conducted as part of a planning or budgeting exercise or as part of management to check on whether or not a project is performing at the level desired. In planning, problems and objectives must be specified and consistent procedures of analysis selected. Objectives might include economic development (efficiency), improved income distribution, environmental quality and sustainable resource use. The key part of any planning exercise is the identification and development of alternative courses of action that contribute to the objectives. The whole process of economic analysis is dependent on having selected the full range of alternatives that are technically feasible. If, for example, one is considering flood control measures and flood plain zoning is not included as an alternative, then the alternative that appears to be the optimum may well be second best.

Within the planning or budget framework, actions are proposed subject to the resource constraints. These actions are then evaluated to select the appropriate course of action. Once the action or project has been implemented, monitoring and evaluation activities can continue throughout the life of the project (figure 1). Ongoing evaluation provides information to managers so they can take needed corrective action if performance is not up to expectations. Planners will also find the monitoring and evaluation studies useful in improving their planning techniques. If they find that their ex-ante evaluation was incorrect, then they need to determine why it was wrong. For example, were the techniques improper or were their projections of future prices too high?

In planning and evaluation, economists must work closely with other

FIGURE 1. Major Elements of a Monitoring and Evaluation System



Source: Adapted from Hyman, 1985.

scientists and resource managers and owners. This is especially true in the formulation of alternatives.

> "Given the biophysical nature of watersheds, many complex physical relationships must be understood and incorporated into the economic analysis. Such factors as sediment delivery ratios, expected impacts of various vegetative regimes, and management programs and hydrologic characteristics may all enter into an economic analysis of a watershed management program." (Easter, Dixon, Hufschmidt, 1986, p. 54.)

Finally, economic evaluations are necessary but not sufficient for most decisions. If done properly, the economic analysis will tell the decision makers the economically most efficient way to use resources given existing institutional arrangements. In other words, what course of action offers the highest economic returns. In addition to the economic evaluation, decision makers may want to have information concerning social, cultural, equity and political factors. The final decision will then be made based on the weights given to the economic evaluation as compared to these other factors. For example, the president may decide to build a flood control project in Senator Waste's district, even though the benefits from the project are less than the costs, because he needs the Senator's vote on a defense bill.

Level of Analysis

One of the key questions that must be decided in project analysis involves the perspective from which the analysis is to be done. Should it be a financial analysis or an economic analysis? Do we count only the benefits and costs that accrue to the entity building the project? If we are only concerned about the benefits and costs that accrue to an individual or a firm, then financial analysis is appropriate. The question then is, what are the actual costs and benefits to the firm? In contrast, if one is concerned about all the benefits and costs to society, economic analysis is the correct approach. However, certain political units may do what they call economic analysis when, in fact, costs or benefits that fall outside the political unit are ignored. This should be called quasi-economic analysis because important impacts are not counted which are external to the political unit. This explains why many inefficient federal irrigation projects have been built in the western United States. From the individual state's perspective, a large water project may be beneficial because the state captures most of the benefits but pays only a small part of the cost. When someone else pays most of the costs or bears most of the negative externalities from your project, it raises the benefit-cost ratio from your limited (state) perspective.

An additional problem can occur which requires both a financial and economic analysis. Suppose you are planning a program to reduce soil erosion in up stream grazing areas. The plan will require an important management and investment input from farmers in upstream areas. This means you need to know if the program meets both the financial and economic criteria. Even if the economic analysis shows that the program should be implemented, it may not satisfy the financial criteria. Farmers in upstream areas must receive enough benefits to give them an incentive to implement the desired practices. If the financial analysis shows that there are not enough private economic incentives, at least four actions are possible. First, the government could provide farmers with added incentives to install the appropriate practices through technical assistance, education or subsidies. Second, alternative programs could be developed that are either more profitable to farmers or required less farmer input. Third, farmers could be required to use certain practices if they wanted to raise annual crops. Finally, the program could be dropped as infeasible due to the results of the financial analysis and nothing further done (no reduction in soil erosion). Thus, economic analysis is necessary to tell us if the project or program meets the social economic efficiency criteria, while the financial analysis is needed to determine if private individuals and firms will perform in a desired manner.

Types of Economic Evaluation

There are several different types of economic evaluations that are used to make comparisons of costs and economic outcomes or impacts. The type of analysis used will depend on the time, data, facilities and staff available to do the evaluation. Clearly, if adequate time and resources are available, one should do a full scale benefit cost analysis. However, if the time is short or data is limited, then something such as cost-effectiveness analysis may be more appropriate.

Three steps are important in an evaluation. First, there must be a time wise description of the physical inputs and outputs for the project or program. This means both positive and negative outputs or impacts must be specified along with inputs. The second step is to place values on the inputs and outputs. Where market prices are available and appropriate, they can provide the necessary values. However, cost and demand studies may be necessary to determine the real cost of resources used and the willingness of consumers to pay for the outputs. Finally, the costs and benefits must be discounted to obtain a present value of benefits and costs so that they can be compared at a common point in time. In other words, the benefits and costs are given weights, depending on when they occur in time. Thus benefits in the distant future have low weights, while those occurring today have high weights.

1. Benefit Cost Analysis

All three steps are necessary in benefit cost analysis and the end result is a single valued measure of project economic efficiency. The analysis requires decisions concerning project life, discount rates and the values of various inputs and outputs. The costs usually start out large and decline while benefits grow over time before falling off near the end of the project. The decisions concerning the project life and discount rate can be very important in determining net project returns, particularly watershed projects because they generally have long term impacts.

Once alternative courses of action are selected and information has been collected concerning their benefits and costs, the most important part of the analysis is completed. Which single measure of efficiency is calculated is not usually critical unless one is involved in a close ranking of projects. The same information must be used to calculate the net present value, the benefit-cost ratio or the internal rate of return (IRR). Each measure has its supporters. The net present value is probably the most straight forward. Yet it can be misleading if projects are compared which are significantly different in size. The benefit-cost ratio tends to be insensitivity to changes in variables and can be altered by decisions concerning whether a cost is a project cost or a negative benefit. The ratio is raised if a cost is classified as a negative benefit and subtracted from benefits rather than added to costs in the denominator of the benefit-cost ratio. The IRR has the advantage of putting off the decisions concerning what discount rate to use. It will provide about the same results as the other two measures unless the benefit and cost streams take some unusual form or the rates of return are unusually high. Since microcomputers make it easy to calculate all three measures, they should all be displayed for the decision maker.

The traditional benefit cost analysis can be expanded to include other concerns. Basically, benefit cost analysis shows whether discounted direct benefits (DB) exceed discounted direct costs (DC).

$$DB > DC \quad (1)$$

However, for many watershed decisions, this is not enough information. One should also determine if the alternative proposed is the least cost alternative. This leads to the second condition that the discounted direct cost (DC_a) of other alternatives must be greater than that of the proposed project.

$$DC_a > DC \quad (2)$$

An important concern in large projects is their potential secondary effects both in terms of costs and benefits. For example, there can be secondary costs (SC) imposed on other regions when crops grown under the irrigation project cause price decreases and shifts in production elsewhere. Secondary benefit (SB) might also arise if there are unemployed resources in the project area. If there are secondary benefits and costs, the first condition should be expanded to include SB and SC, appropriately discounted.

$$DB + SB > DC + SC \tag{3}$$

This, however, is not all the information that should be given the decision maker. Many times environmental impacts are difficult to measure in value terms, particularly preservation benefits and environmental changes that are irreversible. In addition, income distributional impacts are not accounted for in the economic efficiency analysis. Consequently, when environmental and income distributional impacts are important, the benefit cost analysis needs to be supplemented with additional information.

One way of doing this is to develop a system of accounts--one for each of the key program objectives. If economic development, environmental quality and income distribution are the three primary objectives, accounts could be developed for all three. The economic development account would include the benefit cost analysis. The environmental quality account would display any positive or negative effects on the environment in value terms where possible, but otherwise in physical terms. If all environmental impacts can be measured in value terms, the environmental account is no longer needed since it can become part of the economic development account. The income distribution account might include the distribution of project benefits by farm size and jobs created for unemployed or underemployed workers. Table 1 shows what a summary table might look like that goes to the Minister of Agriculture for the final decision concerning which plan to select. Of course, more

TABLE 1. Project Impacts by Objective

Objective	Plan B	Recommended Plan	Difference
National Economic Efficiency	17%	18%	+1%
Environmental Quality	Inundates historical site	Doesn't inundate historical site	+ Doesn't inundate site
Income distribution	300 low-skilled jobs 3 years	200 low-skilled jobs 3 years	- 100 low-skilled jobs 3 years
	450 permanent skilled jobs	425 permanent skilled jobs	- 25 low-skilled jobs permanent

alternative plans and the results of sensitivity analysis could be included as well as accounts for other objectives.[2]

Regional development might be another objective to include in the analysis, if a country has several backward areas where income per capita and employment are low. Where this is the case, the benefit cost analysis could be extended to include an analysis of the project impacts on these backward areas. Input-output and economic base analyses could be used to estimate impacts on regional incomes and employment. Multipliers could be developed that measure the project impacts on employment and income in the key upland sectors, such as forestry, mining, crops, livestock and energy. However, this analysis must be done carefully so that double counting does not occur. One does not want to provide the Minister of Agriculture with final results that present regional benefits as national economic benefits, unless it can be shown that the regional benefits will be net additions to the national economy. For example, secondary project benefits that can be expected to accrue from most typical investments should not be counted as national benefits. Also production increases that just displace production elsewhere in the country are not national benefits.

2. Cost-effectiveness

Cost-effectiveness analysis was developed as a short cut to benefit cost analyses because of time constraints and difficulties involved in estimating benefits. It can be appraoched in two ways. First, one can calculate the least-cost method of achieving a target, such as the amount

[2]Sensitivity analysis will be discussed in detail later in the paper.

of soil lost per hectare. Second, one can determine the largest physical product, which can be obtained from a fixed budget. For example, how many acres of redwood trees can be planted in beta watershed for $100,000. The question is what method or combination of methods will allow us to plant the most trees that can be expected to survive. Providing free trees to land owners might be the lowest cost method to get trees planted. However, without added incentives to maintain the trees, survival rates may be quite low.

> "With the cost-effectiveness approach, two major factors should be remembered before it is applied. First, cost effectiveness does not consider whether the benefits are sufficiently large to warrant the expense. Since resources are usually scarce, there may be other projects or programs more beneficial to society. The second factor is that alternatives frequently do not produce the same level of control; therefore, the choice is not a simple one. For example, assume three projects are being evaluated to reach a target of 100 parts per million (ppm) for some water pollutant. Project A costs $20 million and attains a level of 95 ppm (or a higher level of water quality than the target). Project B cost $35 million and also attains a level of 95 ppm, while Project C costs $5 million and attains a level of 105 ppm. Which project is better?
>
> "Project A is definitely better than Project B on a cost-effectiveness basis. They both reach the same water quality level, but A is much less expensive than Project B. But what about Projects A and C? Project C is the cheapest and just misses the target by 5 ppm. Is it worth the extra $15 million to reach the Project A level? There is no easy answer. In this case, the decision maker will compare the alternatives, the potential damage from a water pollution level of 105 rather than 100 ppm (or 95 ppm), and the alternative uses for the funds." (Easter, Dixon and Hufschmidt, 1986, p. 59).

3. Timing of Analysis

A project or program can be evaluated at many stages in its development, implementation and operation. However, it is probably simplest to think of the evaluation at three different stages (Figure 1). First, ex-ante analysis, which is done in the planning stage to determine whether or not the project should be constructed. Second, on-going evaluation should be done while the project is being implemented and operated. This is to provide managers with information concerning project performance so that adjustments can be made if needed. On going analysis will not generally be as complete as ex-ante analysis and may focus on certain critical inputs and outputs that managers identify. The final stage of analysis is ex-post analysis, which is done after the project has been in operation for enough years, so that performance can be adequately evaluated. For flood control projects, this may mean 15 to 30 years of operation, while for grazing land improvement, it may only require 2 or 3 years.

APPLICATION OF ECONOMIC EVALUATION

The theory behind economic evaluation is now reasonably well understood. The real difficulties arise in its application. Not only are the evaluators faced with information and time constraints, they must also make important decisions concerning what time horizon and discount rate to use. The most difficult task facing the evaluator is estimating project or program benefits, particularly placing reasonable values on outcomes. Recent developments have made it possible to value outcomes of resource conservation and development programs which had been very difficult if not impossible to value in the past. In this section, we will consider a number of the problems that face those trying to evaluate watershed programs and projects.

Planning Area

In any planning and evaluation exercise, the relevant planning space must be identified. For watershed planning, the watershed is clearly the appropriate unit. Yet how far the physical boundaries should be extended downstream is less clear. When downstream damages are important, how far this boundary should be extended is quite important. For example, in studying the Root River watershed in southeastern Minnesota, should one expand the study to estimate its impact on the whole Mississippi river? The silt washed down the Root River goes into the Mississippi River and affects navigation and recreation activities as far down the river as New Orleans, almost 2,000 miles downstream. Economic analysis would suggest that all downstream effects should be included if they would have a significant impact on the program decision. Thus, in the case of the Root River, one would probably carry the analysis only as far as the first one or two locks and dams on the Mississippi River below its confluence with the Root River.

In addition, the boundary selected for management may be different from the one used in the planning analysis because of the need for user participation. If the management unit becomes too large, then it becomes difficult to involve users in the planning, design and implementation stages of the watershed improvement. Since it is usually essential that users of a watershed cooperate in its improvement, user participation must start right at the planning stage. The size selected will vary depending on transportation, communications, institutional arrangements, political jurisdictions and physical conditions. However, the management units will be some smaller part of a river basin. It should be small enough so that there are not strong social and cultural differences within the unit and there is good communication among people in the unit. This means that in remote areas where transportation and communications are poor, the management units should be small relative to areas with good communications. The size of the planning unit used for analysis, in contrast, will be more dependent on extent of externalities that need to be internalized rather than on the need for user participation.

Study Parameters

Two important parameters in the economic analysis must be given to or selected by the evaluator: the discount rate and the time horizon. The time horizon decision is much like the one concerned with the planning area. The answer will vary with the project and the purposes being considered. The major guideline to consider is the useful economic life of the project. After the project is no longer productive, the only other major consideration would be environmental impacts of the project that continue beyond the project's useful life. A further complication arises because the useful economic project life is clearly related to the level of maintenance. With proper maintenance the life of watershed projects can be extended many years beyond the project life typically experienced by resource projects in most developing countries. Thus the time horizon decision must take into account the degree of maintenance that is likely to be achieved.

The discount rate is also important in determining the useful project life. The higher the discount rate, the lower the weight given to future years.

"For any given discount rate and value of benefits (or costs), the more distant the year in the future, the smaller the present value of the output and benefits for that future year. Accordingly, for a project with a long, useful life in terms of outputs (assume 100 years) but with a high discount rate (assume 10 percent), the effective time horizons used would be much shorter than 100 years. For example, "$10,000 received 100 years hence is only worth $1 today (see Table 2). This fact leads to the general rule that the appropriate time horizon for a project is the shorter of (1) the useful physical life of the project, or (2) the economic life of the project measured by the year when discounted net benefits no longer add significantly to the project's net present value.

"This rule presents a quandary for watershed management projects. If the management project is successful in reaching a sustainable yield equilibrium, the appropriate time horizon will be infinite. The net benefits stream has no natural cutoff point. In practice, however, discounting and a desire to simplify calculations frequently result in shorter time horizons being selected. Discounting resolves the quandary since any benefits or costs beyond 40 years will be so small that they will have little impact on the net present value of a project. For the evaluation of watershed management projects, therefore, a time horizons of 30 to 40 years should be sufficient to capture most benefits and costs." (Easter, Dixon and Hufschmidt, 1986, p. 62-63.)

Discounting is the procedure by which benefits and costs are weighted according to when they occur in time so that they can all be compared at the same point in time. People have a preference for receiving funds today rather than in the future and discounting accounts for this preference. The discount rate should reflect the value that people or firms attach to obtaining a good or service today rather than next year or the year after.

The rate one selects for the financial analysis may be quite different from the one used in the economic analysis. The discount rate used for the financial analysis should reflect the real cost of capital for the private firms or individuals (i.e., the market rate minus the inflation rate or the cost of working capital minus the rate of

TABLE 2. Present Value of a Future Net Return of $100 at Four Discount Rates

Time of Net Return (year)	Discount Rate (%)			
	2	5	8	10
0	$100.00	$100.00	$100.00	$100.00
10	82.03	61.39	46.32	38.55
20	67.30	37.69	21.45	14.86
25	60.95	29.53	14.60	9.23
40	45.29	14.20	4.60	2.21
60	30.48	5.35	0.99	0.33
100	13.80	0.76	0.05	0.01

Source: Dixon and Hufschmidt, 1986.

Note: Different combinations of discount rates and time will yield the same present value of some net return received in the future. For example, a present value of almost $14 is yielded by a $100 net return received 100 years in the future if the discount rate is 2%; at a 5% discount rate the present value of $100 received in year 40 declines to $14; for an 8% discount rate the decline to $14 occurs in year 25; and with a 10% discount rate it occurs in year 20 (see the dotted line in the table) inflation).[3] For economic analysis, the discount rate should reflect the social opportunity cost of capital or the social rate of time preference. Unfortunately, if income taxes exist, there is not one rate that equates these two (Baumol, 1968).

The rate selected will have a significant impact on resource investments. A high discount rate means that benefits and costs that occur 10 years or more from now will have very limited value. For example, a $100 net return paid 10 years from now has a present value of $82 if discounted at 2% (Table 2). The same net return discounted at 10% is worth only $38.

Given the importance of the discount rate, what general guidelines should be used in selecting rates for analysis? First, the rate or rates used in the economic analysis will be country-specific and should be established as a matter of government policy. Second, only one rate should be used in any single economic analysis. In other words, different discount rates should not be used for the cost and benefits or for different categories of benefits (environmental or developmental) or costs. Third, the discount rate should not include inflation. It should be a real rate since all prices used in the analysis should be in real terms (deflated for inflation). Fourth, discounting should be done on an annual basis unless it can be shown that the benefits and costs have an unusual pattern over time. For annual discounting, it is assumed that the benefits and costs occur uniformly throughout the year or at the beginning or end of the year.

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[3]This assumes that all prices used in the analysis are also in real terms.

Fifth, the discount rate or rates selected for the analysis usually reflect the social opportunity cost of capital, the cost of government borrowing or the social time preference. Many economists argue that the opportunity cost of capital is the appropriate rate because it indicates what has to be given up if funds are taken out of the private sector to fund public sector projects. A problem arises when some of the products produced in the private sector are judged not to have a very high social value. This could be because of inadequate income distribution which leads to a high demand for luxury goods in a low income country. In this case, one would not look to the luxury goods sector for an opportunity cost of capital. The opportunity cost of capital should be derived from sectors that are producing private goods of high social value, such as the food and agricultural sector.

Finally, for economic analysis one would apply sensitivity analysis using a range of discount rates.[4] This range might be between the cost of government borrowing and the social opportunity cost of capital, adjusted for inflation and income taxes.[5]

Valuing Benefits

In watershed management, a wide range of possible benefits can arise from improved watershed practices and structures. These benefits can

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[4]This would not be necessary if one is only using the internal rate of return (IRR) to calculate project returns. However, even when one used the IRR, a cut off rate of return must be selected below which no project will be built.

[5]Intergenerational concerns raised about long-term projects are probably best handled through taxes or subsidies rather than changes in the discount rate.

TABLE 3 Relationship Between the Goods and Services Associated with Watershed Management Projects and Location

		Location of Goods and Services	
		On-site	Off-site
Types of goods and services	Marketable	I	II
	Nonmarketable	III	IV

Quadrant I Food crops, forage for livestock, animal products, fuelwood, pulpwood, lumber, and other wood products, minerals, water, fish

II Fuelwood, animal products, food crops, forage for livestock, water for drinking, fish, irrigation water, hydroelectric power generation, municipal and industrial supplies

III Aesthetic values, wildlife habitat protection, health benefits of high quality water supplies, protection of aquatic ecosystems, landslide-mudslide control (minimization), preservation of gene pools (natural vegetation and fauna)

IV Protection of downstream riparian and aquatic ecosystems, high quality water for recreation-aesthetic uses, navigation, flood control benefits, sediment control for avoiding losses of reservoir benefits, etc.

Source: Easter, Dixon and Hufschmidt, 1986.

reduce navigation costs. Flood control benefits are measured in terms of damages prevented while irrigation benefits are measured in terms of the increased value of production. In some cases, benefits arise from higheryields of existing crops, while in others it is the production of new higher valued crops or livestock. Navigation and hydro-power benefits come from cost reductions in transportation and power production. The key is to measure these reductions in terms of real cost savings and not just changes in the fees charged for power or transportation which may or may not reflect real resource costs.

In cases where market goods are produced, the valuation can be very straight forward once the quantity changes are estimated. Of course, estimating quantity changes can be difficult, particularly if the shift is to new crops for which we do not know the production response functions. Market prices should be used to value the increases in quantity unless there are no markets, markets are distorted or the project is large enough to change prices. If these problems exist, a demand analysis may be necessary to derive the appropriate price or prices to use in the analysis. Where no market exists, surrogate market approaches can be used.

1. Example of On-site Marketable Benefits

Let us consider a small watershed improvement project that proposes two levels of improvement. The on-site benefit is increased corn production over a 50 year period. This is an example of quadrant I in table 3 (on-site marketable goods benefits). These benefits can be captured by the farmers, so there is no divergence between the one who pays and the one who benefits. However, the individual could have a higher discount rate and shorter time horizon than society which would cause a divergence between the private and social rate of return. Assume that society and the farmer have the same time horizon but quite different discount rates (time horizon and discount rate have the same effect). The assumed discount rate for the farmer is 12%, while it is 4% for society. How does this difference affect decisions concerning on-farm conservation practices?

Consider the case where the farmer has the option of using two different conservation practices. The first, strip cropping, has a much lower per acre cost than the alternative, contour terraces, although this difference is partly offset by higher gross benefits from contour terraces. Contour terraces provide a higher level of erosion control than strip cropping, but the added gross benefits do not make up for the cost difference (table 4). At the two corn price levels considered, strip cropping is always socially profitable while contour terraces are not. The only question arises if the low price of corn prevails. In this case from the farmer's perspective (12%), strip cropping is not profitable (B/C 0.65). However, from society's point of view (4%), it is very profitable (B/C 2.5%). To get the farmers to use stripping cropping at low corn prices, policy instruments or tools must be used. For example, the government could subsidize the strip cropping practice, raise the price of corn or require farmers to use strip cropping if they plant row crops.

The on-site marketable benefits are generally the easiest to value and may be quite important in many watersheds. For grazing land improvements, we would want to measure the change in value of livestock

TABLE 4 On-site Per Acre Benefits and Benefit/Cost Ratios for Watershed Improvement

Type of Improvement	Cost Discount at 4%	Cost Discount at 12%	Benefits Discounted at 4%	Benefits Discounted at 12%	Benefit/Cost Ratio 4%	Benefit/Cost Ratio 12%
			(corn price 2.50/bu.)*			
Strip cropping	$67.64/ac	$41.41/ac	$174.68/ac	$27.05/ac	2.58	0.65
Contour terraces	808.24	586.96	268.67	42.19	0.33	0.10
			(corn price 3.13/bu.)**			
Strip cropping	67.64	41.41	280.07	43.38	4.14	1.05
Contour terraces	808.24	586.96	430.78	67.64	0.53	0.12

*Topsoil depth is 22 cm
**Topsoil depth is 16 cm

Source: Wen and Easter, 1987.

and livestock products produced from the improved grazing rather than the forage produced. This is because markets usually exist for livestock and livestock products, but not for forage.

2. Off-site Benefits

Many of the off-site marketable goods are the same as the on-site marketable goods, except they are in a different location on the watershed. However, some off-site marketable goods such as irrigation water, hydroelectric power and drinking water, are not sold in free markets in most countries.

> "Instead, government agencies sell water and power to users at a fixed rate ranging from zero up to their full cost or more. If price distortions exist, other techniques can be used to determine values. To value irrigation water, for example, the demand for water can be derived from the value of the final products produced such as milk, wheat, rice or vegetables. Similarly, drinking water may be valued by examining health benefits or the value of time saved by having a new, more convenient source of drinking water.
>
> "In cases where markets do not exist, the valuation problem is more difficult. The analyst must look elsewhere to obtain values for many of the environmental quality changes and some of the other externalities. Although use of the watershed as the boundary of analysis internalizes many of the off-site impacts within the analysis, it does not eliminate the measurement problems. Off-site effects such as changes in sediment loads and water quality will be difficult to value. However, considerable work has been done recently to develop procedures for valuing environmental services and effects that traditionally have not been valued. Surrogate market approaches, including travel-cost and property value procedures, and survey-based valuation techniques are now being widely used to value environmental effects." (Easter, Dixon and Hufschmidt, 1986, p. 66.)

3. Examples of Non-marketable Off-site Benefits

An example of a non-marketable off-site benefit would be the reduced cost of navigation. If a watershed project reduces soil erosion and, therefore, the silt load in the river, the cost of dredging to maintain a navigation channel will be reduced. These benefits are measured in terms of the difference in dredging costs with and without the project. Dredging could be reduced in frequency or in the length of time spent during a single dredging period. One can usually obtain the cost of dredging from those doing the dredging, i.e., it ranges from $6 to $8 per cubic yard on the Upper Mississippi River, depending on the equipment used (Wen, 1986). All that is now needed is an estimate of the quantity of silt that would not have to be dredged because the watershed protection project reduces soil erosion. If the annual reduction was 1,000 cubic yards, the average cost savings for a 50 year period discounted at 4% would be $150,375. This should then be compared with the watershed protection cost. If the discounted project costs were $67.64/acre for 2,000 acres, or a total cost of $135,280, the navigation damages alone would cover project costs. In contrast, if watershed improvement had to cover 3,000 acres at a total discounted cost of $202,920, then the costs would exceed navigation benefits by $52,545. However, on-site benefits and other off-site benefits would have to be added to the navigation benefits to determine if total discounted benefits exceed discounted costs.

Another off-site benefit which is likely to be important in many watersheds is the improvement in water quality. This can lead to a number of benefits, including improved recreation and a lower cost for municipal water treatment. Let us assume that the watershed project improves water quality by reducing siltation, which increases people's willingness to pay for recreation. Since there is no market for the recreation activities, there are two general approaches that can be taken in valuing these benefits. One approach is to estimate the travel cost to the recreation site and use it as a proxy for the price of the recreation site. With a number of observations from different distances from the recreation site, a demand curve can be estimated for the site based on the different travel costs and use rates. Other things being equal, individuals farther from the site will use it less often since the travel cost (price) is higher. Demand curves could be estimated with and without the water quality improvement and the difference would be a measure of project benefits.

To illustrate, assume that we were able to conduct an effective travel cost study and determined an annual willingness to pay per user for improved water quality of $30 (Wen, 1986). Again, if we are using a 50 year time horizon and a 4% discount rate, there would have to be 315 annual users to have enough benefits to cover discount watershed protection costs of $202,920.

The second alternative is to ask people how much they would be willing to pay or accept for the improvement in recreation. This is not an easy task and care must be used in asking the right questions so that free rider problems and other potential sources of bias such as starting point bias and instrument bias are minimized. The hypothetical situation posed in the questions, such as a visit to a big game park, must be realistic to the respondent. The payment vehicle must also be appropriate to the person being surveyed. For example, an entrance fee would be realistic payment vehicle for the game park example. In some cases, it is difficult to determine an appropriate payment vehicle for the resource activity being evaluated.

The willingness to pay or accept is the area under an individual's demand curve and is aggregated across users to determine the value of the resource activity. In the case of public goods, this is a vertical summation of the individual demand or bid curves.[6]

Sensitivity Analysis and Uncertainty

There is always uncertainty involved with key variables in benefit cost analysis. The uncertainty increases the farther into the future benefits and costs of watershed practices are predicted. Many of the watershed practices will have a long term pay-off which will be dependent on future prices as well as other uncertain variables. Evaluating soil conservation practices in the 1970s with the high crop prices would have resulted in estimated benefits for the 1980s that were higher than actually achieved. Practices installed based on these prices may no longer be profitable and might be discontinued by farmers.

One of the most widely used methods for considering uncertainty is sensitivity analysis. This involves identifying those variables in the analysis which are the most uncertain. The next step is to try a range of different values for those uncertain variables and see if they change the outcome of the analysis. For example, if the price of corn is uncertain, a range of prices would be tried, i.e., a 25% higher and a 25% lower corn price. Table 4 shows that a 25% higher crop price makes strip cropping profitable even at a 12% discount rate.

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[6]Public goods are those goods in which one person's consumption of them does not subtract from the consumption by others.

Once changes in an uncertain variable are shown to influence the decision whether or not to implement a project, attempts should be made to narrow its range of values. This may require research and additional data collection. For example, a demand study for feed grains could help narrow the price range for corn.

In addition to discount rates and prices, one could also test other variables such as soil depth (Figure 2). The top soil depth appears to be a very important variable in determining whether or not gains in production will be enough to cover practice costs. At top soil depths of over 50 cm, strip cropping is not profitable even at a 4% discount rate and a high price for corn. This means that watershed projects on deep soils will have to provide significant downstream or off-site benefits if they are to be socially profitable. It also means that farmers on deep soil will have little incentive to conserve soil. Therefore, downstream damages may be high in such cases and government action would be necessary to reduce these damages.

Distribution of Benefits and Costs

In watershed management, the importance of the distribution of benefits and costs is easy to see. A major reason for choosing the watershed unit is to try to internalize the costs which flow downstream just like the water. It is difficult to optimize the use of land and water resources on an individual farm since farmers do not bear all of the costs imposed by their cultivation. The external costs go downstream.

Watershed planning and management must take a complete watershed view and count external costs. If social benefits from watershed improvement exceed social costs, then institutional arrangements and implementation tools need to be developed that will bring about the improvement. For example, upstream farmers may not be able to shift fromcassava production to soil conserving crops because of the loss in income. Thus, the first step might be to focus research on developing new cropping systems for upstream areas that will reduce erosion and increase farm income. New institutional arrangements might also be necessary to reduce transactions costs involved in improving watershed management. A new type of extension which employs people from upstream areas may be necessary to take the information to upstream farmers. Many times, upstream farmers are culturally different from those in the extension service (Easter, Dixon and Hufschmidt, 1986). Consequently, the extension service has a difficult time communicating with the upstream farmers. The new extension agents could also help organize farmers into watershed districts or committees so that they can deal with some of the externalities more directly. The organization may also be necessary to maintain erosion control structures that benefit more than one user. However, before such organizations can be started, a new law may be needed that establishes a legal bases for the watershed district. One of the key concerns of such an organization will be how it can finance its activities.

Currently, the lack of private land ownership is being discussed as a means for reducing upstream soil erosion in many developing countries. Whether private ownership will help solve these upstream erosion problems depends on the major source of damages. Privatization will help if most of the soil erosion damages are on-site, i.e. losses in productivity.

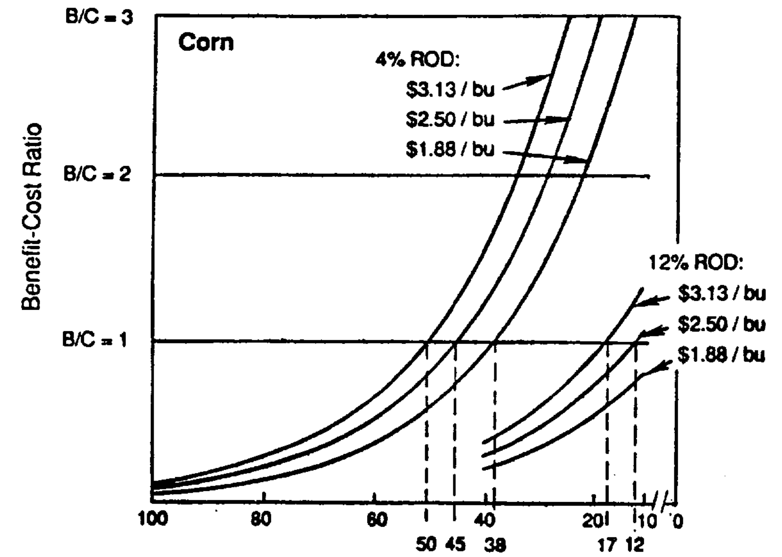

Figure 2. Benefit-cost ratio for strip cropping conservation practices at different corn prices and rates of discount (ROD)

Source: Wen and Easter, 1987.

However, private land owners will ignore most off-site damages. Thus even with privatization one would expect soil erosion damages to exceed the level desired by society if off-site damages are significant. This again relates back to the basic problem that those paying for erosion control do not receive all of the benefits. In watersheds with important off-site damages, means other than privatization will need to be developed to reduce the transaction costs of improving watershed management.

The large transaction costs stem from the difference in location of those imposing the externalities and those benefiting from their reduction. Whether government will have to take direct action or community organizations can deal with these externalities will vary from watershed to watershed and country to country. Much will depend on who bears most of the costs and how large the benefits are from the watershed improvement.

Summary and Conclusions

Economic analysis is an important tool which watershed planners and managers should be using to help improve their decisions. It can tell you the most economically efficient course of action, as well as whether or not a project will use up more resources than it generates. However, economic analysis is only as good as the data that is used in the analysis. If yield and price data are inaccurate, the economic analysis will also be inaccurate. In addition, if the appropriate alternatives have not been selected for evaluation, then the analysis will not identify the most economically efficient course of action. Thus, a special effort must be made to develop a full array of alternatives and evaluators should be given adequate resources to do a good analysis.

The manner in which the results are presented to the decision makers is important. Here a carefully designed sensitivity analysis can be critical in giving the decision maker an idea of the degree of uncertainty involved in the final results. Any important physical effects that cannot be valued should also be described briefly in the final summary report as should any important distributional impacts. The decision maker should not be present with only the "best" alternative. Other alternatives should be provided as a bases for comparison, particularly those that have similar rates of return.

Finally, using the watershed as the unit for planning and analysis has a strong economic logic. Many economic impacts are internalized within the watershed that are an externality to the small scale farm. Thus, using the watershed as the decision unit should, by itself, help improve resource management decisions.

References

1. Baumol, W.J. "On the Social Rate of Discount", The American Economic Review, 1968, VIII (4): 788-802.

2. Dixon, John A. and Maynard M. Hufschmidt, Economic Valuation Techniques for the Environment: A Case Study Workbook. 1986, Baltimore: Johns Hopkins University Press.

3. Easter, K. William, John A. Dixon and Maynard M. Hufschmidt, Watershed Resource Management: On Integrated Framework with Studies from Asia and the Pacific, 1986, Westview Press, Boulder, Colorado.

4. Easter, K. William and John J. Waelti, The Application of Project Analysis to Natural Resource Decisions, 1980, Water Resources Center, Bulletin 103.

5. Easter, K. William, "Monitoring and Evaluation for Integrated River Basin Development and Watershed Management", 1986, Staff Paper P86-27, Department of Agricultural and Applied Economics, University of Minnesota.

6. Hyman, Eric L., "Monitoring and Evaluation of Forestry Projects for Local Community Development", Agricultural Administration 1985, 19: 139-160.

7. Wen, Frank H. and K. William Easter, Soil Erosion and the Loss in Productivity: An Example of the Terril Soil Series in Minnesota, 1987, Station Bulletin 577. Agricultural Experiment Station, University of Minnesota.

8. Wen, Frank H., "Determinants of Optimal Soil Loss Tolerance (T-Value) from a Societal View Point -- the Study of Minnesota Lower-Upper Mississippi River Basin", 1986, Ph.D. Thesis, Department of Agricultural and Applied Economics, University of Minnesota.