

POLICY REFORM AND NATURAL RESOURCE MANAGEMENT

WEEK 1: DAY 5

TAKING ACCOUNT OF ENVIRONMENTAL IMPACTS IN PROJECT ANALYSIS

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1. INTRODUCTION

Most real world policies impact the environment in ways that create conflicts of interest. Suppose that a proposal for a wetland to be drained and cleared for a shopping center is put in place. There are potential gains to the community, which would result from an increase in business and creation of jobs. However, flood-control benefits and habitat for endangered species habitat, among other benefits, provided by the particular wetland would be lost forever. Should the proposed shopping center be undertaken? The decision must depend on whether or not the benefits from building the shopping center outweigh the benefits of preserving the wetland. It is clear from the simple but realistic example that policies that do not take full account of environmental impact may seem more desirable than they actually are.

In this chapter, we present some of the methods that are utilized in appraising policies and projects that impact the environment, with particular emphasis on Cost-Benefit Analysis. We also examine the major problems that arise from using these methods and show how some of them can be handled. The chapter is organized in the following manner. The next section presents an overview of the methods, with a simple illustration on using cost-benefit analysis (CBA). In Section 3, problems that arise from using CBA are examined in detail. Section 4 presents a case study on measuring the costs and benefits of controlling nitrate pollution. Here, we devote a special subsection to the problem of nitrate pollution in developing countries, and Section 5 concludes.

2. PROJECT APPRAISAL METHODS AND COST-BENEFIT ANALYSIS

There are several methods used for appraising policies and projects that impact the environment: cost-benefit analysis (CBA); cost-effectiveness analysis (CEA); environmental impact assessment (EIA); scenario analysis (SA); and risk-effectiveness analysis (REA). The first two, CBA and CEA, are effective for decision making. However, while CEA is used for selecting among alternative policies only, CBA has the advantage of deciding on whether or not a project must be undertaken. The other methods are non-monetary and, largely, they are components of CBA. Thus, in examining CBA and the problems associated with its use, the other methods are also covered.

The essential steps in applying cost-benefit analysis are:

- Defining the project;
- Identifying project impacts including the environmental impacts that are economically relevant. This involves identifying all the cost and benefit areas associated with the project;
- Physically quantifying and calculating a monetary valuation of all the costs and benefits;
- Weighting, discounting, and summing the flow of costs and benefits to obtain a unique Net Present Value (NPV); and
- Performing sensitivity analysis by recalculating the NPV when values of certain essential parameters (e.g., discount rate and life span of project) are changed.

The simple rule of cost-benefit analysis, assuming all costs and benefits are measured in monetary units, is to accept the project if the net present value is positive. When comparing alternative projects, the rule is to select the project with the highest positive net present value. Without going through the mathematical foundations of CBA,¹ the net present value is given by

$$(1) \quad NPV = \sum_t \frac{B_t - C_t}{(1+r)^t}$$

Where B_t and C_t are benefits and costs in time period t , respectively, r is the discount rate, and T is the time horizon or life span of the project.

To illustrate, consider an example in Hanley and Spash (1993) of a proposal to plant trees on a parcel of land that is currently being farmed. Ignore non-market impacts for now. Then the relevant costs would include all the resource using activities associated with the plan, whilst the benefits would be the value of the timber at the end of the project. Table 1 shows the items and the costs and benefits valued at market prices.

Table 1. Costs and Benefit per Hectare

	Year	Value (£ per hectare)
<i>Cost</i> ^a	0	400
Land purchase	0	30
Ploughing	0	650
Fencing	0	580
Planting	1,2,3	430
Weeding	2	70
Beating up	20	40
Brushing	16,20,28	150
Pruning	45	250
Clear felling		
<i>Benefit</i>	45	6500
Value of timber		

^a Costs include capital, labor, and raw materials such as seedlings.

Source: Adapted from Hanley and Spash (1993, p.22).

Note that there is no harvesting until the 45th year when the stand is clear felled. The next step is to convert the costs and benefits into net flows, apply a discount factor, and then calculate the present (or discounted) values. Table 2 shows the result. For year zero, land purchase, ploughing, fencing, and planting costs are added together, and likewise for other costs occurring in similar periods. At a discount rate of 6%, the net present value is negative £1,519.95. The project thus fails the benefit-cost test. Why? The discount rate plays a significant role in this example. Note that costs incurred in year zero count at the full value, whilst the benefit incurred at the end of the project, even though it is large in current value terms, is severely diminished in

¹ For the conceptual and mathematical foundations of cost-benefit analysis, see Dasgupta and Pearce (1972), Hanley and Spash (1993), and Munda (1996).

present value terms. Some of these issues are taken up later in the chapter. As an exercise, try to re-estimate the NPV using 4% and 2% discount rates. What happens? Note also that we assume that the terminal value of the land is zero and the benefits associated with the project come from the timber only. Can you think of any other benefits, including environmental impacts, and how they can be included in the analysis? Will such factors make the project more or less desirable?

Table 2. Discounted Costs and Benefits

Year	Net Cost {-} or Net Benefit {+} (£)	Discount Factor [(1+r) ^{-t}]	Discounted Values (£)
0	-1660	1.0000	-1660.00
1	-30	0.9434	-28.30
2	-100	0.8899	-89.00
3	-30	0.8396	-25.20
4	-30	0.7921	-23.80
16	-150	0.3936	-59.00
20	-190	0.3118	-59.20
28	-150	0.1956	-29.20
45	+6250	0.0726	+453.75
NPV			-1519.95

Source: Adapted from Hanley and Spash (1993, p.23).

By examining the structure of CBA and the simple example, one can perceive several problem areas, especially with respect to steps two, three and four presented at the beginning of this section.

- *Valuation of non-market goods.* In the example on the proposal to develop the wetland into a shopping center, how should valuation of endangered species be done? This and other related issues were taken up in the preceding chapter and so they will not be treated here.
- *Complexity of the ecosystem.* How can we accurately predict the cause and effect relationships between policies and the environment?
- *Discounting and the discount rate.* Should society discount the future? If yes, what discount rate should be used? Are the rights of future generations violated by discounting?
- *Institutional effects.* Is cost-benefit analysis truly objective, or is there an element of subjectivity where institutions can bend the rules to meet their own needs?
- *Sustainable development.* Does undertaking cost-benefit analysis promote sustainable development? How can we ensure that with projects and policies that impact the environment, undertaking CBA does not make an economy's development path less sustainable?
- *Irreversible effects and uncertainty.* How will irreversible and uncertain aspects of the environment be included in a CBA?

In the next section, we try to answer some of the questions raised and shed light on issues surrounding others. For further discussion on these, see Hanley and Spash (1993).

3. MAJOR PROBLEM AREAS IN APPLYING CBA TO ENVIRONMENTAL CHANGE

3.1. Complexity of the Ecosystem

One of the difficult tasks in applying CBA to environmental change lies with establishing cause and effect relationships between policies and the environment. It is a difficult task because "the static interrelationships and the processes of change in almost all ecosystems are extremely complex" (Hanley and Spash, 1993, p152). This can be illustrated with an example of the benefits of reducing sulphur oxides levels in the atmosphere. It well established that sulphur oxides emissions contribute to acid rain, which has detrimental impacts on ground and surface water and forests. To begin, we will need a model that relates a reduction in sulphur oxides emission to their concentration in the atmosphere, which are in turn related to acid rain, and finally to economic welfare. Sulphur oxides are emitted when fossil fuels are burnt and in certain industrial processes. In the atmosphere, sulphur oxides are oxidized into sulphates, which are deposited in water bodies and on plants through rain or by direct contact. The problem is that the oxides and sulphates in the atmosphere can be transported by wind over very long distances. Therefore, emissions in one country can have detrimental effects in other countries. Since externalities are by themselves complex (e.g., establishing liability), combining them with ecosystem effects increases the complexity of the problem many times.

How should an analyst consider these complex relationships? Hanley and Spash (1993) cite some substantial research effort targeted at modeling complex interactions of economic policy and the environment. Examples include the International Institute for Applied Systems Analysis (IIASA) model of acid deposition in Europe; and the Centre for Agricultural and Rural Development (CARD) model of pesticide use and transport in the Mid West corn belt of the USA. Maler (1990) used the IIASA model in his study on the acid rain problem in Europe to estimate the benefits of reducing emissions.

There are two main lessons to be learnt from the criticisms against using economic methodology to analyze environmental systems.² First, economic and environmental systems evolve together and, so, as environmental systems change, due to economic growth, economic activities need to be altered to accommodate the changing environment. Second, since individuals lack information about the environment, we should use community or collective preferences rather than individual preferences in making environmental decisions. The idea is that collective values are more than the sum of parts.

3.2. Discounting and the discount rate

Another major controversial issue with respect to CBA is the idea of discounting. Discounting is carried out to calculate the Present Value of a flow of benefit or cost associated with a project. If it turns out that benefits outweigh costs in any time period, then NPV is positive for any discount rate. However, benefits rarely exceed costs in all time periods. Usually, costs and benefits are

² See for example Norgarrd (1989)

incurred at different times of the project life span. Since the effect of the discount rate is that benefits and costs incurred further into the future have lower present values, it becomes relevant what discount rate is chosen, if at all. For current decision making that uses the NPV criterion, beneficial projects such as growing oak trees become unattractive, whilst harmful projects such as creating and storing nuclear waste does not less burdensome. As the discount rate rises, the time bias also increases, i.e., beneficial projects become even more unattractive and harmful projects seem less problematic.

Should society discount the future? Ethical arguments have been presented in favor of a zero discount rate. Consider, for example, the egalitarian rule, which is based upon a fair allocation. The argument proceeds as follows. Suppose that individuals are required to make inter-generation allocation decisions that will affect them from a position in which they cannot be sure about the way the decision will affect them. That is, individuals do not know which generation they will be drawn into, or whether they will be affluent or poor. Then the rational decision that will be agreed upon by all individuals is one in which all the costs and benefits occurring within any time period are equally weighted (see Hanley and Spash, 1993, for details). This outcome is only sustained by a zero discount rate. Should society maintain a zero discount rate? On the other side of the debate, Olson and Bailey (1981) argue that if capital is productive and there is a demand for investment funds, then a zero discount rate is wrong. Otherwise, consumption will remain at the subsistence level and never rise above it. Several other arguments have been made in favor of discounting. For example, temporal location of future generations disqualifies them from an equal treatment, and since future preferences are unknown, they must be excluded from the decision-making process and focus attention on actions of current generations for which preferences are known. Another argument is that the human race will become extinct at some point and so increasing current consumption prevents potential resource wastage in the future. While it has been argued that the uncertainty of future events also supports discounting, Fisher (1981) shows the uncertainty can lead to increased or decreased consumption depending on the type of uncertainty.

The two sides of the debate can be summarized along the lines of Lemons (1983) into four categories, depending on whether there exists a moral duty on present for future generations. (1) No moral obligations beyond the immediate future exist. In this case, the discount rate is positive and high; (2) Moral obligations to the future exist, but the future is assigned less weight than the present. Here, the discount rate is positive and low; (3) Moral obligations to the future exist and the future is assigned equal weight compared to the present. The discount rate in this case is zero; and (4) Moral obligations to the future exist, but the future is assigned more weight than the present. The fourth scenario was introduced by Hanley and Spash (1993) for a symmetrical analysis.

Even if we accept that the discount rate should be positive, there is the question of what the appropriate rate should be. Under perfect competition, the interest rate would be a sufficient choice. The interest rate is a unique equilibrium defined by the intersection between savings and investment, where the marginal rate of return on capital equals the marginal rate of time preference (see Ritson, 1977 for further discussion). This rate shows how consumers and producers behave via rate of time preference and opportunity cost of capital, respectively. Some

economists have argued that this rate may be too high and that a lower social rate might be appropriate. Marglin (1963) argues that there are future external benefits to savings/investments, which would be undersupplied by the free market because of the free-rider problem associated with public goods. Thus, it would be necessary for governments to intervene and apply a lower discount rate to public projects, compared to the rate the private sector applies to private projects. Another argument is that individuals behave differently when they are consumers in the market place compared to when they are members of society. As consumers, they attach a higher discount rate to future costs and benefits, compared to the latter role. Furthermore, Ramsey (1928) and Pigou (1932) argue that while individual consumers have a finite life expectancy, society, as a whole, lives in perpetuity. Therefore, the two rates should diverge. Otherwise, a rate that is higher than the social rate would not provide adequate investment for future generations. Since future generations are not directly represented in current decision making, the government must intervene and take future preferences into account by applying a lower discount rate to public projects.

Over time, the choice of a discount rate has evolved into a political issue. This is especially the case for (public sector) projects that impact the environment. For example, Page (1977) observes that about 80% of the dam projects approved in 1962 in the US would have been rejected had the discount rate used by the Army Corps of Engineers been raised from 2.5% to 8%. Noting that the discount rate is something that is chosen and not measured, Heal (1981) shows the choice depends on how we view intergenerational equity and characterize the economy. For example, the social discount rate of 5% that was previously used in the United Kingdom, was selected by civil servants as a value lying between the rate of return on private investments and the consumption rate of interest. For the benefit of the Forestry Commission, the rate has been lowered to 3%. In the United States, it is believed that the Nixon Administration chose a discount rate near the top of the standard government rate, which ranges from 3% to 12%, in an attempt to achieve a reduced public expenditure (Lind, 1982).

While the search for an appropriate discount rate continues, perhaps the best strategy for environmentalists and for society, as a whole, is summarized in Hanley and Spash (1993, p.200) as follows:

1. impose a constant environmental capital stock constraint on investment decisions across the public sector,
2. adopt a maximin strategy to protect choice when there is uncertainty about the assimilative capacity of the environment, substitution possibilities between natural and man-made capital, and damage costs associated with development.

3.3. Institutional effects

The person or institution conducting the cost-benefit analysis has considerable discretion in how the analysis is conducted. For example, the method used for valuing non-market goods and services, choice of discount rate, and the relevant population over which gains and losses should be aggregated, are potential areas for bias. The problem is that CBA can be utilized to achieve personal needs. For example, Bowers (in Hanley and Spash, 1993) argues that water authorities in England conducted appraisals of large-scale land drainage projects to maximize the probability

that the projects passed the cost-benefit test. These projects were mainly designed to allow farmers to alter their production activities towards more profitable activities. Bowers argues further that even though farm gate prices were distorted by support payments to the extent that the marginal social benefits of additional farm outputs were generally below the farm gate equivalents, farm gate prices were nevertheless used to value outputs. Abstracting from this and the example about the Nixon administration, one can envisage that an agency may lobby for the right to use a specific discount rate that favors acceptance of the type of projects it promotes. This is especially the case when certain projects are particularly sensitive to the choice of the discount rate.

3.4. Sustainable development

A buzzword that has been around for quite some time and is much in use is "sustainable development". What is sustainable development? How do undertaking cost-benefit analyses of all projects and policies that impact the environment affect an economy's development? There are several definitions of sustainable development (see Johannson, 1995; Pearce *et al.*, 1990; Pearce and Turner, 1989). However, in order to answer the above questions, consider the following four alternative definitions of sustainable development via Pezzey (in Hanley and Spash, 1993). (1) Non-decreasing consumption through time; (2) Non-decreasing utility through time; (3) Non-decreasing stock of total capital (man-made and natural) through time; and (4) Non-decreasing stock of natural capital through time. The first two definitions are less appealing. While the first definition is restrictive, since it assumes that individuals only derive satisfaction from the consumption of produced goods and services, the second definition deals with an unmeasurable concept of utility. The last two definitions, which are concerned with the maintenance of opportunity and allow later generations to choose their own opportunity, seem more appealing. The third definition introduces an element of substitutability between man-made and natural capital, but this may be misleading since there are several elements of the natural capital stock that may be impossible to be substituted for by man-made capital. Thus, if man-made capital and natural capital are poor substitutes for each other and if some aspects of the natural capital stock are viewed as vital to future generations, then a subset of the natural capital stock must be maintained intact (Hanley and Spash, 1993). With this view in mind, the fourth definition, non-decreasing stock of natural capital through time, seems very attractive. However, the way in which natural capital is measured becomes problematic. If it is measured in physical terms then we cannot aggregate oak forests and blue whales, for example. If it is measured in monetary units, then the implication is that it wouldn't matter if blue whales become extinct as long as oak forests are planted to make up for the loss, in monetary units. Of course, this measure would hardly be desirable.

A solution would be to compartmentalize natural capital where it cannot be fully aggregated, and then endeavor to keep each compartment constant. Van Pelt (in Hanley and spash, 1993) has suggested pollution, pollution assimilative capacity, biodiversity, and renewable and non-renewable resources as possible categories. For non-renewable resources such as oil, which have fixed finite stocks that declines with extraction and use, the only way to maintain a constant stock is for new discoveries to equal extraction. Otherwise, only a zero extraction rate would be consistent with maintaining constancy. With a comprehensive compartmentalization, sustainable

development, defined as non-decreasing stock of natural capital, can be achieved in monetary terms using CBA. Consider a project with net environmental costs, say loss of wildlife habitat. Then instead of the cost-benefit rule that prohibits any project with net environmental costs, we can create some other (shadow) project that has net environmental benefits equal to or greater than the net environmental costs associated with the original project. Tree planting and physically relocating wetlands are examples of shadow projects that are conceivable in physical terms. A strong condition of the proposal is where the condition holds in each period. A weak condition, on the other hand, is where, over the life span of the project, the net discounted sums of the environmental gains and the environmental losses are non-negative. Thus, the condition can be estimated in present value terms (see Hanley and Spash, 1993; and Pearce *et al.*, 1990). It should be emphasized that even with the environmental compartments, there are difficulties with the above approach. The assumption is that there is perfect substitution among natural capital within a particular compartment and all relevant environmental impacts are assessed in monetary units. The weak form of the condition also sets up the undesirable likelihood that a small quantity of current environmental improvements would be used to offset a very large quantity of environmental damages in the future. Finally, the issue of who will pay for the shadow project is unresolved.

Hanley *et al.* (in Hanley and Spash, 1993), on the case of the Cardiff Bay barrage development project, report some of the problems that may arise with shadow projects. On the project, the plan was to construct a barrage across the Cardiff Bay for recreational benefits. This would convert the bay from a saltwater area into a freshwater lake, and the wintering grounds for about 5,000 to 6,000 wildfowl and waders would be lost. The birds would have to move elsewhere or die. As a substitute, a shadow project at a nearby site consisting of 23 hectares was proposed for the 165 hectares of the Cardiff Bay, which has been classified a Site of Special Scientific Interest. Whether or not the 23-hectare site qualifies as a shadow project is open for debate.

3.5. Irreversible effects and uncertainty

The conversion of wetlands and clearing of rainforests can have some irreversible impacts, but projects that lead to, for example, the extinction of species are extreme cases. The most important issue concerning irreversible developments is that the benefits of preservation are lost forever when such developments are undertaken. In the example to develop the wetland into a shopping center, suppose that the benefit of preserving the wetland can be estimated for the current year, both in physical and in monetary units. Assume further that these benefits remain constant in real terms. Then we can estimate the future value of preserving the wetland, and using the cost-benefit test as discussed earlier on, we can proceed with the development of the shopping center if the net present value is greater than zero.

In the example, we have assumed that preservation benefits are constant over time in real terms, but we have not made any assumptions about development benefits. Thus, the straightforward benefit-cost test may be very unrealistic. First, developments (the shopping center) often have a life span and so the benefits associated with them are not likely to be perpetual. Krutilla and Fisher (1975) have argued that development benefits, especially for projects where the benefits are in terms of cost savings over alternative technologies, will decline over time. This means

advancement in technology will diminish the cost savings that are tied up in the project. Therefore, development benefits are likely to grow at a negative annual rate. Preservation benefits, on the other hand, are likely to grow at a positive annual rate, and there are several reasons to expect this. For example, increasing relative scarcity as wetland stocks decline, increasing information about the benefits of preservation of wetlands, and increasing demand for environmental goods and services as incomes and population rise (see Hanley and Spash, 1993; Hanley and Craig, 1991). Thus, with declining development benefits and increasing preservation benefits, the net present value, which was presented earlier on, should be modified. Equation (2) depicts the Krutilla-Fisher model of irreversible development.

$$(2) \quad NPV' = \sum_t \left[\frac{D_t}{(1+i-g)^t} \right] - C_o - \sum_t \left[\frac{P_t}{(1+i-\tilde{r})^t} \right]$$

Where D is development benefit, C_o is initial development cost, P is preservation benefit, i is the discount factor, g is the annual rate of decline in real development benefits, and r is the annual rate of increase in real preservation benefits. According to equation (2), the negative rate of g reinforces the discounting process while the positive rate of r offsets it. This model presents an insightful approach at dealing with irreversible developments, since it explicitly considers asymmetric growth rates in development and preservation benefits. It can be deduced that development projects that have negative g and positive r , may hardly pass the benefit-cost test if C_o or P is substantially high, or D is substantially low. See Krutilla and Fisher (1975) for applications of the model to downhill ski developments, mineral extraction, and hydro schemes in North America, and Hanley and Craig (1991) for applications to wetland losses.

There are, however, some limitations associated with the Krutilla-Fisher model. Estimation of g and r can be difficult and they may be unstable over time, and the initial values of D and P can be difficult to measure. There is also the problem of measuring future preservation benefits foregone. Using the preferences of current individuals for the estimation may result in conflict with future preferences.

In this section, we have examined major problems that arise in applying cost-benefit analysis to evaluate projects and policies that impact the environment. Ecosystem complexity, discounting and choice of discount rate, institutional effects, sustainable development, irreversible effects of development, and uncertainty about resource stocks were the problem areas examined. We tried to answer some of the questions raised and also shed light on issues surrounding others.

4. COSTS AND BENEFITS OF CONTROLLING NITRATE POLLUTION

In this section, we examine the costs and benefits of controlling nitrate pollution. First, we present an overview of nitrate pollution, specifically on why it is important to do so, sources of nitrate pollution, and some of the policy options that are available for controlling it. A special subsection is devoted to the problem and threat in developing countries. Finally, some of the attempts made at estimating the costs and benefits are presented. We will not dwell on the details of the methods used in the estimations, since they are treated elsewhere in this book.

Only the general models, estimates, and some of the problems encountered, with respect to the discussion in the previous section, are presented in some detail.

4.1. Overview of nitrate pollution

Why do we need to control nitrate pollution? There is concern over pollution of groundwater and surface water because excessive nitrate levels have been linked to two health problems. One is methaemoglobinaemia or blue-baby syndrome, which is caused by oxygen starvation in bottle-fed infants. The other is stomach cancer, which is caused by nitrites and N-nitroso compounds. These compounds are believed to be carcinogenic and they are converted from nitrates by bacteria in the human body. However, low levels of nitrates are not harmful and so government agencies do set upper limits for nitrate concentrations in drinking water. For example, the European Community (EC) has set the maximum safe level of nitrate in drinking water at 50 mg/l. There are other environmental effects of increasing nitrate levels in water bodies. These pertain to the phenomenon of eutrophication, which is associated with the decaying of its algal matter. Though nitrates are nutrients for fish as well as algae, as nitrate levels rise, algal growth blooms and can reach such a level that the decaying of its algal matter uses up and depletes dissolved oxygen. Its decayed matter also chokes off sunlight and oxygen. Algal blooms have been linked to oxygen starvation in some fish, and the toxins released by blue-green algae have been linked to some fatalities in dogs and sheep. Hanley and Spash (1993) report that, in 1990, the National Rivers Authority (NRA) found 30 inland waters that were affected by the toxins of blue-green algae. This led the government to ban catching shellfish in certain areas when it was found that shellfish caught in those areas were contaminated with toxins from blue-green algae.

What are the sources of nitrate pollution? Nitrate pollution is a classic example of a non-point pollution, and it is well documented that nitrate, a compound of nitrogen, is leached into rivers, streams, and groundwater by the movement of water through the soil. Nitrogen is vital to the growth of plants because it is a major part of amino acids and proteins. When plants take up nitrogen, they do so in the form of ammonium (NH_4) or nitrate (NO_3) compounds, via the process of mineralization and nitrification, respectively. Nitrogen enters the soil through fixation by some plants (legumes), rain, plant and animal residues, and application of inorganic and organic fertilizers. Plants absorb some of this nitrogen as they are growing. Some of the remaining nitrogen in the soil is lost to the atmosphere by evaporation and denitrification. Some, in the form of nitrate (NO_3), is leached through the soil by the action of water or remains in the soil in either organic or inorganic forms. Table 3 shows inputs and outputs of nitrogen from agricultural land in the UK in 1978. Nitrogenous fertilizer constitutes about 43% of nitrogen inputs in the soil. About 25% of the nitrogen that is not taken up by plants (crops and grass) are leached through the soil.

Table 3. Nitrogen Balance for Agricultural Land (1978)

Inputs	N (kt)	Outputs	N (kt)
Rain	275	Crops and grass uptake	1367
Seeds	14	Leaching	326
Fertilizer	1150	Ammonia volatilization	
Sewage	26	livestock wastes	536

Livestock wastes	1020	crop wastes	50
Silage effluent	9	sewage	9
Straw	15	Balancing figure ^a	380
Feed wastes	9		
Biological fixation	150		
Total	2668	Total	2668

^a Lost through denitrification and immobilization into organic nitrogen.

Source: Royal Society (in Hanley and Spash, 1993).

It is widely accepted that conventional agricultural practices are the main cause of nitrate pollution. Increased use of high-yielding crop varieties that require high inputs (including high fertilizer application rates, large tracts of land, and ample water) combined with reduced input prices have greatly increased the potential for nitrate to be leached into surface and ground water. While several factors affect the leaching process, it is believed that nitrogenous fertilizers are applied in excess because farmers do not take other factors (water availability, soil structure, plant requirements, etc.) into consideration (Bijay-Singh *et al.*, 1995). For example, leaching risks are very high when rainfall or irrigation is high, evaporation is low, and crop demand for nitrogen is low. Table 4 shows the world's annual consumption of nitrogenous fertilizer for selected years region. Even though current consumption appears to have stabilized, and declining for in certain countries, growth in consumption rates over the past decades cannot be ignored. From 1975 to 1990, world consumption almost doubled, with Asia and Oceania leading the pack with a scale of about 3.6 and 2.7, respectively.

Table 4. World Nitrogenous Fertilizer Consumption by Region and Economic Class ('000 MT)

Region/Class ^a	1960/61	1975/76	1980/81	1985/86	1989/90	1992/93	1994/95
Africa	222	1251	1757	1957	2044	2143	2054
Asia	1348	10005	21450	27069	35910	39803	40195
Europe	3935	12244	14323	15356	15728	11334	11956
Oceania	33	188	273	386	504	595	731
North and Central America	2774	11117	13181	12545	13253	13415	13598
South America	148	764	1438	1566	1792	1880	2383
Developing Countries	n.a.	12171	25057	31356	40703	n.a.	n.a.
Developed Countries	n.a.	30737	35718	38472	38486	n.a.	n.a.
World	9170	42908	60776	69830	79189	74511	73555

^a For data beyond 1992, the former USSR is split into two. Belarus, Estonia, Latvia, Moldova, Russian Federation, and Ukraine are part of Europe, while the other independent republics are part of Asia.

Source: FAO (1965, 1979, 1992, and 1996).

Despite the importance of nitrogenous fertilizer in agriculture, the health risks and other environmental effects associated with nitrate pollution cannot be overemphasized. Thus, the need to control nitrate pollution is real. However, the analysis of nitrate policy is rendered complex and difficult because of the dynamic nature of the problem. It is believed that nitrates can take up to 40 years to be leached through the soil to the groundwater, depending on the soil profile, the underlying rock structure, and the mode of water movement through these layers.

Therefore, detecting nitrates in groundwater supplies for the first time now may have been the result of agricultural activity around the late 1950s. Hanley and Spash (1993) argue that increased nitrate levels in boreholes in many parts of Southern England in the late 1980s was due mainly to the ploughing-up of permanent pasture during the Second World War to facilitate increased home cereal production. This dynamic aspect of the problem reflects some of the concerns about ecosystem complexity that was discussed previously. What this means is that policies targeting reductions in the amount of nitrate leached currently may have no direct impact on the quality of water until the late 2030s.

4.2. Nitrate pollution in developing countries

On the whole, it may seem that nitrate pollution does not constitute a major problem in developing countries. However, with nitrogenous-fertilizer consumption on the rise (see Table 4), and especially in areas where irrigation is available, the situation is bound to change. The threat is real, since nitrates take up to forty years to travel through the soil to the groundwater. It is believed that low nitrogen fertilizer application rates consistent with the system of crop production in the past, have given rise to the negative nitrogen balances in most parts of the developing world. How long can the negative nitrogen balance be maintained? Actually, fertilizer use in developing countries tends to be concentrated in a few districts, which give rise to major concern. For example, Bijay-Singh *et al.* (1995) reports that in 1991/92, even though Latin America's share of the total world consumption of nitrogenous fertilizers was only 4.5%, Brazil and Mexico alone accounted for 56% of that. In Africa, whose consumption share was merely 1.69%, Nigeria consumed 17% of that. Similar trends, where a few countries represent major consumers of nitrogenous fertilizers, are encountered in many other regions.

Even in countries of relatively low nitrogenous fertilizer consumption, the problem is not removed, since other factors such as soil texture, humidity, precipitation, gradient, and cropping systems come into play. For example, Osiname *et al.* (1983) find that under conditions of high precipitation and heavy overcast, such as in the humid tropics, there is a high chance that at least 50% of mineral-N initially in the soil may be lost through leaching between the onset of rain and plant establishment. Gamboa *et al.* (in Bijay-Singh *et al.*, 1995) reports that 65% of applied nitrogen was leached in Costa Rican alluvial soils under a maize crop, and Charreau (in Bijay-Singh *et al.*, 1995) observed progressive losses of nitrogen in West-African ultisols as rainfall increased.

While nitrate content of groundwater is in general low, the range of values that have been detected is alarming. For example, in the northeast region of Argentina, the nitrate content of groundwater ranges from 5 to 200 mg/l, but in the northwest region of Buenos Aires province, it ranges from 10 to 1300 mg/l (Mugni and Krase in Bijay-Singh *et al.*, 1995). This reflects the difference in cultivation and fertilizer use practices between the two regions, with the former lacking in these practices. In addition, Uma (1993) found nitrate levels from over forty wells around the City of Sokoto, Nigeria ranging from 20 to 100 mg/l. The values were higher for wells around agricultural farmlands compared to wells around forested and residential areas.

With increasing nitrogenous fertilizer consumption, the threat of nitrate pollution in developing countries is eminent as it has shown in certain areas, especially areas under intensive agricultural activity. Another important factor to consider is that poor countries may not have options (e.g., treating contaminated water by reverse osmosis or ion exchange, drilling deeper wells, and bottled water) for drinking low-nitrate water.

4.3. Costs of controlling nitrate pollution

Controlling nitrate pollution can be approached in two ways: (1) reducing the amount of nitrates entering or leached to the environment or (2) removing the nitrates once they have entered the environment. Most of the analysis carried out here deals with the former option only. The latter option, which includes treatment and removal methods such as blending with low-nitrate water, ion exchange, and reverse osmosis, is mainly useful when the target is drinking water. To arrest eutrophication as well as target drinking water, and when farmlands dominate non-point emissions, removal methods tend to be impractical. A combination of the two approaches, however, proves to be helpful in certain cases.

Costs associated with reducing the level of nitrates entering the environment. Policy options that are utilized to for control nitrates originating from agricultural sources are:

- Reducing inorganic nitrogenous fertilizer applications either through price incentives (e.g., a nitrogen tax) or through quantity standards (e.g., fertilizer application rates).
- Reducing organic animal-manure applications either by a head tax on livestock or restrictions on livestock stocking rates.
- Better management of nitrate applications and farming practices in general. Farmers can reduce the level of nitrates leached from their property by implementing Best Management Practices (see Yadav and Wall, 1998). Avoiding large-scale ploughing of pastures and nitrate application rates during periods of high precipitation and/or low crop requirements are examples of practices that would reduce nitrate leaching.
- Land use patterns can also be an instrument of policy. Government agencies can enforce "protection zones", which are off limits to agricultural activity, in sensitive areas, such as around wells. Alternatively, prohibiting drilling of wells around intensive agricultural areas may also prove to be helpful.

Nitrate pollution is a classic example of non-point pollution. Therefore, taxes or permits specified in terms of inputs (nitrogenous fertilizers, livestock, and land use) rather than nitrate emissions are relevant here. Success of these policies hinges on the accuracy of information about application and emission rates. Due to the complexity of the linkage between nitrogen applications and nitrate emissions, substantial difficulty is encountered in achieving a target reduction in nitrate concentration in either surface or ground water. However, once a model of nitrogen application and nitrate emissions is built, the costs associated with achieving a given nitrate level can be estimated.

Most of the studies on estimating these costs have focused on the costs to farmers of various policies, within a comparative framework. Andreasson (in Hanley and Spash, 1993) compare three policy alternatives aimed at reducing nitrate use on the Swedish Island of Gotland from 100

mg/l to 30 mg/l. The target of 30 mg/l is the upper limit in drinking water supplies set by the Swedish government. The three nitrogen-use policy options considered are fertilizer tax, tradable permits, and non-tradable quotas. Under the tradable permit system, each farm is initially allocated some fertilizer permits and each permit specifies the amount of fertilizer that can be used. Permits can then be bought and sold among farms. Under non-tradable quotas, each farm is specified a fixed amount of fertilizer, but farms cannot trade their quotas. Andreasson uses a hydrological model to predict the necessary reduction in nitrate application and leaching that would attain the target of 30 mg/l. The model produces a target reduction in nitrogen application by 5,100 tonnes/year. Of this, about 43% could be met through improved management of livestock wastes (i.e., reducing organic manure application) and the remaining by about 50% reduction in inorganic nitrogenous fertilizer application. The policy implications are shown as Scenario B in Table 5. Anticipating uncertainty over the comparative leaching rates of manure and fertilizer, a second set of analysis, shown under Scenario A in Table 5, is carried out where only a 14% reduction in inorganic nitrogenous fertilizer application is targeted. That is, nitrate leaching from manure is deemed more important. Andreasson uses an econometric approach to estimate nitrogen demand equations for each policy using time series data over the period 1948-1984. Table 5 shows the results.

Table 5. Costs of Reducing Nitrate Pollution in Gotland, Sweden

Policy Alternative	Resource Costs (Krona Millions)		Farm Income (% of Total Income)	
	Scenario A	Scenario B	Scenario A	Scenario B
Non-Tradable Quotas	24.1	34.2	-10.0	-15.4
Fertilizer Tax	18.7	21.2	-13.9	-12.4
Tradable permits	18.7	21.2	-7.6	-9.0

Scenario A: Leaching is higher from manure.

Scenario B: Equal leaching rates.

Source: Andreasson (in Hanley and Spash, 1993).

For both scenarios, the tax and tradable permits give identical resource costs, but taxes reduce farm income by a greater percentage. Caution is required in comparing these two policies, since zero transactions costs and perfect competition are assumed in the tradable permits market. In reality, asymmetrical information between permit buyers and sellers may not allow potential gains from trade to be realized. Quotas are the most costly under both scenarios, except in terms of farm income where it is cost-efficient compared to taxes.

In another study, Pan and Hodge (1994) also analyze three alternative approaches (fertilizer tax, leaching tax, and land use permits) for controlling nitrate pollution. Their study is based on a groundwater catchment area of about 20,700 hectares in Cambridge Chalk in Eastern England. This area supports intensive agricultural production activities. Studies prior to Pan and Hodge's and covering the same area, had concluded that if leaching rates remained uncontrolled, the nitrate concentrations would reach 150-200 mg/l by the beginning of next century. The EC recommended maximum level is 50 mg/l. Using a hydro-geological model, which incorporates the relationships between land use, production, and drainage water quality, Pan and Hodge

estimate farm gross margins when a leaching rate of 22.6 kg of nitrogen/hectare/year is imposed. This leaching rate is EC-recommended to achieve the upper limit of 50 mg/l in drinking water supplies. Table 6 shows the results of Pan and Hodge. While the nitrates leached are identical for all three policies, fertilizer application is lowest for the fertilizer tax.

Table 6. Gross Margin, Fertilizer Use, Leaching, and Cost-effectiveness of Policy Alternatives

	N—leaching Kg/ha	N—application Kg/ha	Gross Margin £/ha	Gross margin + tax £/ha	Cost effectiveness ^a £/mg NO ₃ /ha
Base run	45.1	168.7	578.9	578.9	n.a.
Fertilizer tax	22.6	32.2	250.7	334.9	4.9
Leaching tax	22.6	67.3	238.4	414.7	3.3
Land use permits	22.6	82.0	402.0	402.0	3.5

^a Average cost per hectare for reducing each milligram nitrate per liter in leaching water.

Source: Pan and Hodge (1994, p.109).

The difference in application rates is due to differences in the underlying land use patterns associated with the alternative policies. For example, legumes are planted under the fertilizer-tax option, but not under the other two. The results also show that controls on leaching (i.e., leaching tax) represent the most cost-effective method of controlling nitrate pollution. This is expected because the leaching tax tackles the problem directly. However, the difficulties with monitoring nitrate concentrations and establishing liability of individual producers, rules out the leaching tax as a practical policy option.

Between these two above studies, we have examined the costs associated with five policy options for controlling nitrate pollution: fertilizer tax, fertilizer application quotas (tradable and non-tradable), leaching tax, and land use permits. Deciding on which policy option to choose is left to the reader. However, an important thing to consider in making the choice is the income effect associated with each policy. Some of the questions that need to be answered are: Who gains and who loses? Which of these two groups are more politically powerful? How are permits initially allocated?

4.4. Benefits of reducing nitrate pollution

As we saw at the beginning of this section, high nitrate levels in water bodies are associated with two major problems: eutrophication and health risks. Therefore, reducing the amount of nitrate in receiving waters would yield economic benefits, since either one or both of these problems are minimized, if not eliminated. Benefits can be estimated in one of two ways: either directly using surveys or by the costs that would have occurred without protection, which may consist of costs associated with procurement and treatment of the contaminated water, and delivery of the treated water. The latter is also referred to as avoidance costs, and it represents a lower bound of the total benefits, since it does not contain intrinsic and non-use values.

Benefits associated with reducing eutrophication. There are benefits to both commercial and recreational fishing activities by reducing nitrate concentration levels. For commercial fishing, the benefits could be estimated by looking at the potential economic rents, whilst for recreational fishing, change in consumers' surplus might be considered. Silvander and Drake (in Hanley and Spash, 1993) investigate the benefits of reducing eutrophication on both commercial and

recreational fisheries in Sweden. They show that while nitrates, as nutrients, cause the growth rate of fish to increase and support a higher population, the negative effect of eutrophication outweighs the high growth rate and population of fish. Decomposition of algae burns up oxygen and the decomposed matter chokes off sunlight, which inhibits the production of oxygen by plants. Thus, fish populations are deprived of oxygen and the toxins produced by the algae also harm the fish. Silvander and Drake argue that the positive and negative effects of increasing nitrate levels would reach a point where the fish stock crashes. They use this extreme scenario for commercial fisheries and aquacultures of shellfish to estimate the loss of potential industry rents. The total industry profits less the labor cost are estimated at 65 and 41 million Swedish Krona (SK) annually for ocean fisheries and aqua-culture (shellfish), respectively.

For recreational fishing, Silvander and Drake estimate the welfare losses as a result of the total disappearance of popular species such as cod, mackerel, and plaice. Here, they use a Contingent Valuation Method (CVM) to elicit willingness to pay (WTP) of anglers (i.e., the users) for a management program that would preserve the fish populations at their current levels. Willingness to accept (WTA) is also elicited as compensation for disappearance of the fish stocks. The mean WTP and WTA values are 332 and 4,912 SK per person, respectively. These values show the disparity between WTP and WTA measures that was discussed in the previous chapter. A CVM is also conducted on non-users within the study area. The mean WTP is 296 SK per person. Aggregating users and non-users over the relevant population gives a range between 1,321 and 1,547 million SK.

Combining the two estimations (loss of commercial and recreational fisheries), the total annual cost of eutrophication ranges from 1,427 to 1,653 million SK. Conceivably, this range represents a lower bound on the benefits, since estimates for commercial fisheries do not include non-use values. It is not surprising therefore that the value for recreational fishing is much higher. Values estimated with contingent valuation methods are believed to include non-use values.

Benefits associated with reducing health risks. For measuring the benefits associated with reducing health risks, the most popular approach used is the contingent valuation method, where individuals are asked to express their WTP for a reduction in the nitrate levels of their drinking water supplies. Table 7 shows estimates in a few areas with their respective nitrate concentration targets.

Table 7. WTP for Reducing Nitrate Concentrations in Drinking Water

Study	Area	Target	WTP (per unit) ^a	WTP (total)
Hanley	Eastern England	[50 mg/l	£12.97	£10.8 million
Edwards	Cape Cod (USA)	[10 ppm	\$1,650	n.a.
Silvander and Drake	Sweden	[50 mg/l	244-933 SK	2,304 million SK

^a The estimate from Sweden is on a per person basis. The other two are on a per household basis. Source: Compiled from Hanley and Spash (1993).

Yadav and Wall (1998) estimate the costs of reducing nitrate concentration levels in drinking water as a result of using different combinations of distillation systems (reverse osmosis (RO) and ion exchange), drilling deeper wells, and bottled water. Their study is carried out in the

Garvin Brook Rural Clean Water Program (RCWP) area of southern Minnesota, USA, which covers a groundwater recharge area of about 46,516 acres, including some rural communities and two municipalities, Lewiston and Utica. Three scenarios of nitrate contamination are included in the research. The current situation is the situation in which about 35% of the wells in the rural communities exceed 10 mg/l and the remaining wells are below this level. That is, the wells in Lewiston and Utica are not affected. In future scenario 1, 55% of the wells in the rural communities and the city of Lewiston are above the 10 mg/l. In future scenario 2, 75% of all the wells are above the 10 mg/l. Yadav and Wall estimate the costs associated with reducing the nitrate concentration in the contaminated wells to 10 mg/l using different combinations of drilling deeper wells and using distillation systems in the rural areas and drilling deeper wells only in the urban areas. Table 8 shows a summary of their estimates. Assuming that response option 2 prevails in the rural areas, the potential total annual monetary benefits of groundwater quality improvement is US\$ 58,894 under the current situation and US\$ 104,230 and US\$ 139,863 under the future scenarios 1 and 2, respectively.

Table 8. Costs of Water Supply in the Garvin Brook RCWP Area

	Annual Costs (US\$) ^a		
	Current Scenario	Future Scenario 1	Future Scenario 2
Rural Contamination			
<i>Response Option 1</i>			
2/3 of people affected drill new wells	61862	97211	132561
1/3 of people affected lease RO system	11248	17675	24102
Sub-total	73110	114886	156663
<i>Response Option 2</i>			
1/3 of people affected drill new wells	30931	48606	66281
1/3 of people affected lease RO system	11248	17675	24102
1/3 of people affected buy RO system	16715	26267	35818
Sub-total	58894	92548	126201
<i>Response Option 3</i>			
1/3 of people affected drill new wells	30931	48606	66281
1/3 of people affected buy RO system	16715	26267	35818
1/3 of people affected do nothing	0	0	0
Sub-total	47646	74873	102099
Urban contamination			
Lewiston (drill new wells)	0	11682	11882
Utica (drill new wells)	0	0	1980
Sub-total	0	11682	13662
Total Costs (Rural and Urban)	47646—73110	86555—126568	115761—170325

^a Annual costs are in 1993 nominal dollar terms.

Source: Adapted from Yadav and Wall (1998, p500).

5. CONCLUSION

In this chapter, we have seen that ignoring environmental impacts in project analyses can lead to biased and undesirable outcomes. Project appraisal methods available for taking account of

environmental issues, with special emphasis on cost-benefit analysis for effective decision-making, were presented. A simple illustration of how to implement the benefit-cost test for project selection was presented. The major problem areas surrounding cost-benefit analysis and how some of these problems could be solved were discussed. Issues surrounding other problems were also discussed. Finally, nitrate pollution was chosen as a case study to illustrate how economic analysis can be applied to complex environmental issues. Some of the policy options available for controlling nitrate pollution and the costs and benefits associated with each option were examined.

As a decision-making tool, cost-benefit analysis reduces a large amount of information, varying in kind and quality, to a single figure - a net present value. This means that goods and services, especially environmental non-marketed goods and services, which have no value data would be treated as though they make zero contributions to benefits, costs, and net present value. While this shortfall associated with non-market goods and services has been reduced by the substantial progress in developing techniques (e.g., contingent valuation, hedonic price and travel cost methods) for their valuation, there is still room for bias in evaluating projects and policies that impact the environment. In order for CBA to be an effective decision-making tool, all obtainable information associated with the project being evaluated must be documented. Also, sensitivity analysis must be performed for crucial technical coefficients (e.g., discount rate, project length, and environmental prices) including best- and worst-case scenarios. The CBA should thus be inconclusive if sensitivity analysis demonstrates that the net present value is negative under certain conditions but positive under other conditions. There is also inverse sensitivity analysis for environmental goods and services without value estimates. Here, the question to be answered is how large should the unvalued benefits and/or costs be in order for the net present value to be reversed?

Finally, other valuation techniques should be considered when economic justification for a particular objective is irrelevant. For example, the cost-effectiveness analysis seeks to identify the least-cost method of achieving a particular objective without asking whether the objective makes economic sense.

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