ECONOMIC AND SOCIAL COMMISSION
FOR ASIA AND PACIFIC REGION

ACCOUNTING AND VALUATION OF ENVIRONMENT

VOLUME I

A PRIMER FOR DEVELOPING COUNTRIES

UNITED NATIONS
NEW YORK 1997

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FOREWORD

The concept of economic growth through sustainable development is being widely accepted by countries within and outside the ESCAP region. Among the contemporary issues receiving government attention is the integration of environment and development in decision making. Towards that end, Agenda 21 which was adopted at the Earth Summit in 1992 recommended the establishment of systems for intergrated enviromental and economic accounting.

Under the guidance of the ESCAP Committee on Statistics, the secretariat is charged with responsibility for promoting statistical capability in the region. Accordingly, the Statistics Division developed in 1992 a multiple-year project entitled Systems of Enviromental and Resource Accounting, for which the Government of the Netherlands has generously provided financial support. The project enabled five countries in the region to undertake studies for the presentation of environmental and resource accounts for specific resources of major concern to their countries. It also enabled the development by consultants of guidelines for environmental and reource accounting. The project culminated in a regional Seminar on Enviromental and Resource Accounting, which was organized at Seoul from 27 to 31 May 1996, for which the Government of the Republic of Korea, through its Korea Environmental Technology Research Institute, provided supplementary financial support. The Seminar recommended that a publication based on that meeting be produced for wide circulation.

The Seminar noted that few countries in the region had undertaken compilation of environmental and resource accounts. It is hoped that the publication will be useful to statisticians embarking on this type of work in their countries. The publication will be issued in two volumes. Volume I contains a Primer on Environmental and Resource Accounting, while volume II presents selected proceedings of the Seminar.

The ESCAP secretariat is grateful to the Government of the Netherlands and the Government of the Republic of Korea for their financial support. We wish to express our appreciation to the principal consultants, Dr. Kirit Parikh and Dr. (Mrs.) Jyoti Parikh of the Indira Gandhi Institute of Development Research (IGIDR), Mumbai, India for their excellent contribution to the project. The consultants have been involved and provided valuable guidance in various activities of the project, including advising country experts in the preparation of country studies, the development of the guidelines as presented in volume I, and the conduct of the Seminar. We are grateful to the Indira Gandhi Institute of Development Research for organizing the present publication, with funds provided by the Government of the Netherlands.

Adrianus Mooy
Executive Secretary

PREFACE

The purpose of this guide or primer is to give a brief idea of what is involved in environmental accounting and valuation. It is meant as an overview for those who are interested in this subject as well as to tempt them to try these techniques in their own countries. While valuing a single phenomenon, such as estimation of costs of air pollution degradation for a city, can be carried out by many researchers on their own, an intergrated accounting exercise needs to be supported by national statistical offices and requires team efforts and government commitment. However, before such a commitment is made, the countries require an overall perspective of what is involved in terms of concepts and methodology. We hope that this primer provides such a perspective.

The guide is organised as follows : Chapter I argues why such efforts are needed, chapter 2 introduces the basic concepts and describes different approaches to environmental accounting and how one can follow a step by step process leading to a system of integrated economic and environmental accounts, especially to the one proposed by the United Nations Statistics Division. Chapter 3 sheds light on different methods of valuation required for different purposes. The last chapter shows how selected environmental assets may be valued.

We are grateful to our colleagues at the Indira Gandhi Institute of Development Research , Vijay Laxmi and G. K. Tripathy for their help; to Sudhir Sharma, Nandini Hadkar, Barnali Nag and G. S. Hari Priya for research assistance and to Mahesh Mohan for his secretarial assistance.

Jyoti K. Parikh
Kirit S. Parikh

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Why Account for Environment?

1.1 Environment Accounting

Environmental degradation associated with economic development and population growth is visible in many places. The change in the quality of land, air and water as well as the loss of flora and fauna raise concern about such costs of development. At times, the trade-off is between short-term development and environmental quality. But sometimes even economic benefits are not commensurate with the losses on the environmental front. Such environmental losses are not justified on any grounds and are indicative only of carelessness and negligence. Our understanding of environmental issues has become a bit more sophisticated over the past few years. Today, the *environmentalists* do not question development, but only certain types of development and the *economists, technocrats* and *administrators* admit that not all development is desirable. However, more progress is needed to formally reconcile the concerns of both the groups.

The production of any economic good requires inputs and use of machines or fixed capital. It is well known that in the process of production a machine gets worn out, its useful life is reduced and that for any calculation of income earned from this process of production, one must account for the depreciation of fixed capital. As an example, let us consider cloth weaving. Cloth can be produced using inputs of yarn and labour and a loom as fixed capital. If a power loom is used, electricity will be needed as an additional input. At the end of a year, what is left is the cloth that has been produced and a slightly worn out loom. The income derived from this process is the value of the cloth minus the cost of yarn (and electricity) minus the depreciation in the value of the loom.

However, apart from man-made inputs and machines, many economic activities also require natural resources and environmental inputs. We use land, water, air and so on for economic activities and consumption. As long as they are available in plenty, these are considered *free*. But nonetheless, we use them and this changes their quality.

Energy is used as an input in most economic activities. When fossil fuels are used, air is drawn in for the combustion process. The exhaust air contains some combustion products and does not have the same quality. Similarly the use of water also degrades its quality.

Often however, natural resources regenerate. For example, the productivity of land improves when it is left fallow. The load of carbon dioxide in the air or organic wastes in water get absorbed and the air and water quality are regained in time. As long as human activity is at a level below the regeneration capacity of the natural environment, there is no secular decline in the quality of these resources. However, with increasing population and economic activity, the quality of the environmental resources can no longer be taken for granted. The income derived by using natural resources does not qualify to be considered as *sustainable income*.

The degradation of natural resources, or loss in the quality of the environment, imposes a burden on present and future generations. Depleted soil gives less output for the same level of inputs, i.e., higher cost of production. One may even have to forgo production for some time to permit natural processes to regenerate the soil. If degradation goes beyond a certain limit then such natural regeneration may not even be possible and positive amelioration measures at some additional costs may need to be taken. Degradation implies that the present generation borrows from the future generations. It may not be wrong to borrow from the coming generations if we leave them richer and more able to deal with the problems we leave behind. However, they should not have their options closed for them. Thus, we need to know how much of a resource we have used up and how much of a burden we leave behind.

Such accounting of environmental resources-use does not normally take place in the process of economic activities because the costs of environmental degradation and resource depletion are not borne by the economic actors who cause them. A firm keeps track of the depreciation of machines it owns. If it does not do so, it will soon go out of business. On the other hand, a firm can go on causing damage to the environment without any effect on its own profit for years to come. The effects of environmental resource depletion may be outside the profit and loss account of a firm, but they are not outside the accounts of society, the nation, or mankind. A firm may not bear the burden of pollution, congestion and degradation, but other members of society surely do.

Thus, as a community, nation and the world, we should keep track of our resource base and the state of our environment. It is not easy to value natural resources. There are many conceptual difficulties and measurement problems, let alone paucity of data. Yet, in spite of all these problems and limitations on the accuracy and reliability that they impose on the estimates, natural resource accounting is worth carrying out in order to keep track of the environmental consequences of economic activities. Such accounting can alter our perception about the kind of development that is desirable and in turn, the policy choices we make.

The important role played by accounting in policy debates and popular perception can be appreciated by considering the example of natural income accounts. Estimates of GDP (gross domestic product) are so ubiquitous that one forgets that such estimates are little more than fifty years old. The first national accounts were published in the United States of America in 1942. In spite of the imperfections and conceptual difficulties (for example, if a man marries his maid and if they do not employ another maid, national income decreases as unpaid household work is not valued in national income), government's use these accounts to guide their actions and people use these estimates to judge the performance of governments.

If we do not incorporate environmental resource changes in these accounts, we will be judging the governments' performance using a defective biased scale. Even economists classical notion of income, as given by Hicks (1946), is as follows:

> "The purpose of income calculations in practical affairs is to give people an indication of the amount which they can consume without impoverishing themselves. Following this idea, it would seem that we ought to define a man's income as the maximum value which he can consume during a week, and still expect to be as well off at the end of the week as he was at the beginning. Thus when a person saves he plans to be better off in the future; when he lives beyond his income he plans to be worse off. Remembering that the practical purpose of income is to serve as a guide for prudent conduct, I think it is fairly clear that this is what the central meaning must be."

Taking this as a guiding notion it is clear that the depreciation of natural assets must be subtracted from the conventional notion of income to arrive at a figure of net income that society can consume without impoverishing itself.

The notion that natural resource capital contributes to production just as man-made capital does, has been well recognized by the classical economists. Thus, land rent constituted a part of the value added. Alfred Marshall (1990) recognized the contribution that natural capital made to the production of goods and services. Thus, he implicitly recognized natural capital as a factor of production.

Thus, accounting for natural capital and its depreciation is but a logical extension of the ideas of national income accounting.

1.2. Score Keeping on Natural Assets

It is possible to argue that some of the neglect of natural resources by governments could have been avoided if their depreciation was properly accounted for by the standard national accounts. Accounting for natural resource depletion and degradation could have been done without any new conceptual problem. All it would have required was a change in convention as to what is and what is not included in national accounts. Depreciation of man-made assets is accounted for in the United Nations System of National Accounts (1993). This is done by taking the change in the market value of assets, when it is available; otherwise the capitalized value of the changes in the stream of rents or net revenues from the asset is used.

1.2.1 Warning signals on depletion of assets

Using the same notions, depreciation due to deforestation, over-fishing, soil degradation, mining of exhaustible resources etc. could be accounted for. Timely warning signals for policy action may be given before these resources reach dangerous levels of depletion, if environment accounting practices are followed. While valuation is very important in the context of Integrated Environmental and Economic Assessment (IEEA) and should be done, natural resource accounting needs to be much more comprehensive if we are to encourage the formulation of policies for sustainable development. See Bartelmus and others, (1991), Lutz (1993), Milon (1995) and the United Nations (1993).

The preparation of national resource accounts and their regular publication can bring much needed accountability of public policy. These accounts will reveal the real income of the nation, what it borrows from nature, what this generation borrows from the future, as well as how much some members of society gain at the cost of others.

1.3 Objectives of Valuation and Boundaries of Accounting

While we raise valuation issues in the context of IEEA, here we should emphasize that valuation techniques go beyond serving the purposes of IEEA. We mention these other purposes as a point of departure. Thus, what you include in valuation depends on the purpose for which it is done. Valuation is a larger issue than IEEA. It is an exercise that can be carried out at a local, regional and national level. It could also be used for environmental policy at a local level, for deciding investment priorities among environmental objectives etc. IEEA is a national level exercise, and is only one of the many reasons for valuation.

1.3.1 Relative environmental priorities

Valuation is useful for deciding relative environmental priorities. For example, how much should the Mumbai municipality spend on air, water and noise pollution reduction and how much on solid waste management? If the degradation costs are estimated for each, one can understand which is relatively more harmful to them and to whom (poor or rich)? Here, the accounting boundary may be around a city, a region or a state.

1.3.2 Cost effectiveness of environmental investment

Natural resource accounts can also be useful in carrying out cost benefit analysis for a single investment decision. If the social cost of degradation far exceeds the private costs, then certain investment in abatement may be justified, be it from the private or public sector. Here, the accounting boundary could be the affected area or community.

1.3.3 Assessing trade-offs

Valuation can also help in deciding trade-offs between environment and economic development. For example, how much degradation should be tolerated for leather exports? Here, the accounting boundaries can be around production units in a given area.

1.3.4 Environmental impact assessment

Valuation can also be useful for Environmental Impact Assessment (EIA), where the accounting boundary is around a project. Over the lifetime of the project, what are the environmental impacts it will generate? If valued appropriately and compared with the benefits of the projects, it will ensure the desirability of the project. However, this could mean assessing one area over several years (i.e., going across time).

Numerous case studies in valuation have already been accumulated. Several books and monographs cover a variety of case studies. See for example. Bartelmus and others (1993), ENRAP (1994), Repetto and others (1989, 1991), Van Tongeren and others (1991), and Young (1993).

1.4 Approaches to Valuation

1.4.1 Accounting versus economic approaches

There is often a dispute among national account statisticians and economists about how to value environment. While the accounting approach prefers to record only the actual financial transactions, the economic approach prefers to go beyond this and looks at it with a larger perspective. However, this worries the statisticians and accountants as it strays into a domain of considerable uncertainties.

For example, in the case of health damages, the accountants would like to record only the actual expenditure on illness. So they would prefer the cost of illness method. However, the economists prefer approaches that go beyond illness. They want to also account for the loss in human capital that calls for disability adjusted life years (DALY), or statistical value of life (SVOL) or known

loss of IQ in children (e.g. due to lead (Pb) pollution). Even loss of work or output due to absenteeism because of illness is valued in the economic approach. All these are relevant damage costs to be valued for local or regional decision making concerning projects or activities. In the national accounts, however, the fall in output is already captured and may lead to double counting. For these and other valuations of environment, economists would like to consider opportunity cost approaches or even subjective approaches such as the contingent valuation method. However, the accountants wish to stay close to the financial transactions, otherwise they may have problems of inconsistency, subjective judgement and at times, double counting. They prefer to be within the confined boundaries of the framework of national accounts, include only market transactions, and do not like to introduce arbitrary elements in it. Due to the tight system in which they operate, they can *merely transfer* the costs from one head to another or they can enlarge the scope of the accounts.

On the other hand, the true damages of environmental degradation remain uncaptured in the pure accounting approach. If the deaths due to pollution are not valued it may not lead to a correct environmental policy. Thus, if one draws a boundary around an environmental problem, economic approaches are most useful. However, for the purpose of national accounts, one may have to limit the cost of degradation and depletion to actual costs or make limited use of surrogate methods. If national accountants value deaths due to environmental degradation, they have to value deaths due to all socio-economic activities to be consistent across sectors. Even that will have problems because human lives themselves are not a part of the national accounting system. Then, how can one have depreciation in human lives in the accounts without bringing in arbitrary elements? Table 1.1 demonstrates where and how far the accountants and environmental economists would like to go.

Table 1.1 : Where accountants stop and how far economists go

Environmental Issue	Accounting Methods (A)	Economic Methods (B)
Health damages	Cost of illness	(A) + DALY* + SVOL **+ loss in IQ
Value of National Park	Travel cost	Contingent Valuation Method

* Disability adjusted life years in case of morbidity.

** Statistical value of life. (For more discussion on this, see Chapter 3)

By and large, one might say that the accounting approach will give an underestimate due to minimum coverage and economic approaches may give an overestimate due to subjective valuation. Yet, the range of estimates is worth considering for correct appreciation of the value of environmental resources. The accounting approach, by being conservative, may not justify any action, if the degradation costs are too low and the poor are unable to pay through financial transactions for the damages caused to them by the environmental degradation. On the other hand, for the same situation the economists' approach may call for public action.

Having classified the two perspectives and their strengths and weaknesses, we proceed to discuss all other issues keeping this distinction in mind.

1.4.2 Environmentalists' approach

In addition to the accountants' and economists' approaches, there is also the environmentalists' perspective. The latter see our economic system as a part of natural systems and not the other way around. Initially, the concept of valuation of environment was met with surprise, if not disbelief, from ecologists and environmentalists. Why do we want to value environment? It is priceless! Unsubstitutable! These are valid arguments but are similar to those questioning the value of life. While one cannot put a price on a specific individual's life, there is a concept of the statistical value of life which may be different in each country. Without this, there may not be compensation for lives lost due to accidents, disasters and even negligence. Not valuing life will aid those who should be offering compensation for it and not the individuals at risk. Even if such compensation may often seem meaningless to the survivors, no one would deny that the world is better with than without it.

Similarly, the price on environmental amenities - such as lakes, rivers, mangroves, national parks, coral reefs and so on - may be a difficult proposition but needs to be addressed. Everyone wants a clean environment; no one denies that. Yet, environmental conditions deteriorate because it is a common property resource which everyone wants to use but no one wants to pay for.

Fortunately, many experts have gradually come on board with a variety of concerns and suggestions. Valuing anything requires information on price **(P)**

and quantity **(Q)**, then we have the value **V = P x Q**. In the case of environment, both are difficult to measure but physical description is comparatively easier than putting a price on it. Even if we can value only some of the many benefits of the ecosystem, partial valuations are more useful than no valuation at all. However, these will be valued only for mankind (anthropocentric) and will be difficult to value for other species.

Valuing the ecosystem, genetic diversity and the indigenous knowledge system - that helps to use these resources - will be difficult for some time to come. Thus, one can only proceed with an anthropocentric (human-oriented) valuation of the environment with full awareness that at best this can be an underestimate involving only the interests of mankind and not all species.

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2

From the System of National Accounts (SNA) to IEEA: The Framework

2.1. From SNA to IEEA: The Basic Concept

We begin with the basic conventional System of National Accounts (SNA) in the input-output framework. It provides a description of the flow of commodities and services into different uses: input in production of goods and services (intermediate use) and final uses such as private consumption, public consumption, investment and exports. These add up to domestic output and imports. Along with the flow of commodities and services is also the flow of income generated in the process of production as value added consisting of wages, profits and rents and its disposal for various final uses. This is shown schematically in Figure 2.1.

Each row in the input-output framework describes a commodity flow balance as follows:

Domestic production + imports = Intermediate use in production processes + Private (individual) consumption + Public (collective) consumption + Investment to create produced assets + Exports

If we have detailed data on how imports flow in the economy, this can be split up and commodity flow equations can be written separately for domestically produced goods and imported goods.

When the balance equations for all the goods and services are added up in money terms, i.e., after multiplying the term in each equation by the price of the good or service, we get the national income identity.

(Value of all domestic production − Value of intermediate use) = Value of private consumption + Value of public consumption + Value of all investment + Value of exports − Value of imports

The left hand side is the gross value added or gross domestic product, GDP.

Output Users / Source Input	Intermediate inputs into domestic production activities			Private consum-ption	Govt. consum-ption	Invest-ment	Export	Import	Output
	Agri-culture	Indus.	Services						
Agriculture Industries Services		[A]		C	G	N	E	M	X
Value added Wages & salaries Profits Rents									
Gross Output									

Figure 2.1: Conventional national income accounts

In Figure 2.1, we have assumed that all entries are written in monetary terms. The above equation is represented by the last line in the figure. Each column in Figure 2.1 can be looked upon as an activity, which requires inputs supplied by the various flows and produces the output listed at the bottom of the column. Thus, it is an input-output (I-O) framework. We may also note that the columns on the left side refer to the production activities. The matrix [A] in Figure 2.1, which describes the flows of input in the production activities, is called the I-O matrix. The columns on the right refer to the final demand activities. In subsequent figures, we will represent these two sets of activities, production and final demand, schematically as two separate blocks.

We may note that the input-output framework of Figure 2.1 only deals with the flow of goods and services over a period, which is generally a year. It does not involve any stocks of assets. Depreciation in man-made fixed capital assets is subtracted from the GDP to obtain the net domestic product, NDP. The stocks of assets also change over the year due to investment and depreciation. Hence accounting for changes in them is instructive. Therefore, the revised SNA (United Nations, 1993) has a capital stock identity :

closing stocks = opening stocks + investment – depreciation + revaluation due to market price change.

The same two accounts, the flow and capital stock, also constitute the IEEA except that the concept of capital stocks is enlarged to include non-produced natural assets as well. The simplest IEEA is thus as shown in Table 2.1. The numbers in Table 2.1 are only illustrative with an arbitrary choice of monetary units such as Rupees, US dollars and so on.

In Table 2.1, line 2 corresponds to the last line in Figure 2.1 and gives the flow of national income. Column 3.1.1.1 shows how man-made assets change. Starting with an initial value of 991.3 additions were made due to investment of 61.8 from domestic product and 6.2 from imports. However, depreciation due to use in production caused a reduction of 23.0. A further reduction of 25.3 took place due to natural and multiple causes (e.g., earthquakes, fires, etc.). Price changes led to revaluation by 138.1. The final value of the closing stock was 1149.1. Thus, the asset stock identity shown is as follows:

1149.1 Value of closing stocks	=	991.3 Value of initial stocks	+	61.8 Investment from domestic production	+	6.2 Investment from imports
	-	23.0 Depreciation due to use	-	25.3 Loss due to natural causes	+	138.1 Value gain due to change in price

Table 2.1: Version 1 of the IEEA: SNA concepts (summary table) - general concepts

		1.1 Domestic production of industries	2. Final consumption		3. Non-financial assets (uses and stocks of assets)			4. Exports	5. Total uses	
			2.1 Indi-vidual	2.2 Collec-tive	3.1.1 Produced assets of industries		3.2 Non-pro-duced natural		Domestic origin	Foreign origin
					3.1.1.1 Man-madel	3.1.1.2 Natural				
		1	2	3	- 4	5	6	7	8	9
1	Opening stocks				991.3	83.1	1756.4			
	Use of products of industries									
2	Domestic products	184.1	148.7	42.5	61.8	1.4	7.3	71.6	517.4	
3	Imports	39.9	26.3		6.2	0.0		2.1		74.5
4	Use of produced fixed assets	26.3			-23.0	-3.3				
5	Net value added/NDP	267.1								
6	Gross output of industries	517.4								
	Other volume changes									
7	Due to economic decisions				0.0	0.0	7.0			
8	Due to natural and multiple causes				-25.3	0.0	-4.1			
9	Revaluation due to market price changes				138.1	12.6	410.5			
10	Closing stocks				1149.1	93.8	2177.1			

Source: United Nations (1993).

Choice of units is arbitrary as this is only an example.

If we can write similar accounts for produced natural and environmental assets, we have an IEEA.

Note here that the first version of IEEA merely adds some new types of assets for which capital stock identities are to be prepared. Thus, in addition to man-made produced assets of industries, the IEEA also includes produced natural assets such as plantations and non-produced natural assets such as environmental assets. The most important new step is valuation of non-produced natural and environment assets for which market prices are not available. Thus, we see that the basic concept of IEEA is just a logical extension of the SNA. We elaborate these arguments here and show how we can go from the SNA to IEEA in a logical, incremental way.

2.2. The Environmental Joint Products of Economic Activities

It is obvious that the conventional economic accounts do not identify any of the environmental and natural resource inputs that are used for production, but which are not priced in markets. The fact that the costs are external to the firm is the main reason for much of our environmental degradation. It is therefore, not surprising that conventional national economic accounts do not include them.

We need to extend these conventional accounts in many ways for our purpose. First, we have to consider the various emissions and effluents associated with the economic activities of production and consumption. Second, we should ensure that the sectoral detail accounts for the resources of interest.

In the conventional accounts, as already mentioned, each column can be looked upon as an activity which requires as input the items supplied by the various rows and produces the output listed at the bottom of the column. To each of these columns, we can append the associated emissions, effluents and pollutants that it generates as joint products. For example, to the agricultural production activity we may add chemical residues in the soil, in the surface run-off from farms and in the subsoil water. If there is soil erosion due to cultivation that may also be added. Similarly, for the activity of power generation, we may add the emission of SO_X, NO_X and CO_2 as well as the particulates spewed in the air. It is difficult but not impossible to work out, at least approximately, environmental joint products for each activity in the I-O matrix -

production and consumption. For example, the engineers, plant managers, equipment manufacturers or experts in various disciplines can tell you how much water effluent or air exhaust or noise is generated by each production and consumption process. Figure 2.2 shows schematically the extensions of the conventional national accounts needed to incorporate environmental consequences of economic activities. The shaded rows and columns represent splitting up of rows and columns to obtain greater detail as described in the following section. The rows of environmental joint products are appended to describe how each production and consumption activity (column) affects the environment. These are also called physical accounts of environment.

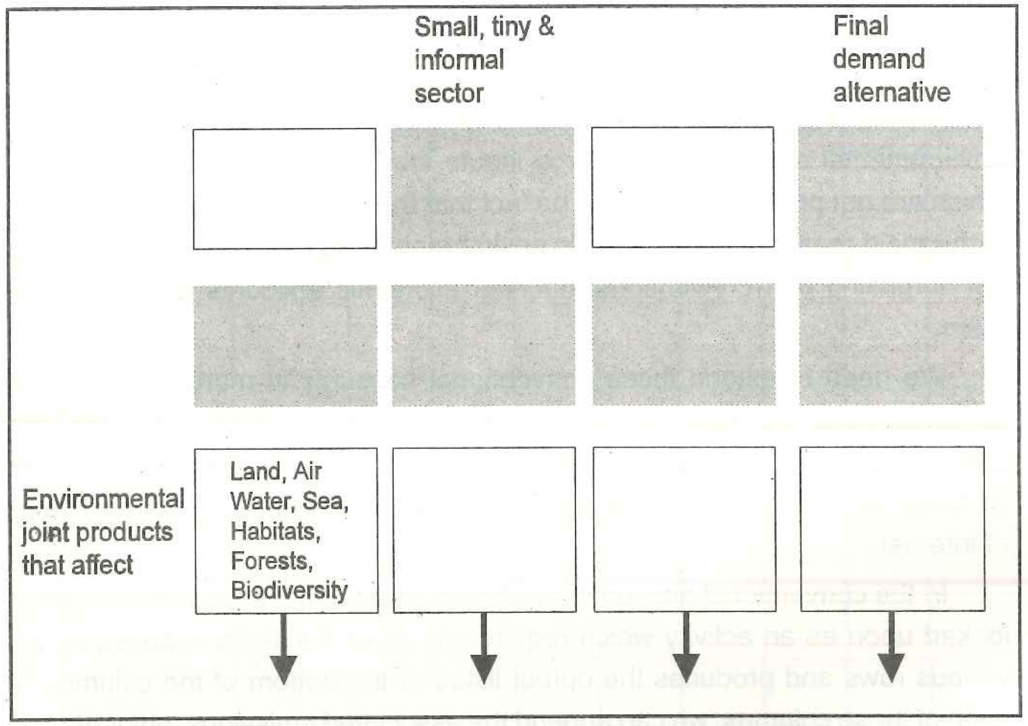

Figure 2.2: Extension of conventional national accounts for environmental accounting

2.3 Expanding Sectoral Details for Alternative Techniques

In conventional economic accounts, those activities which produce the same output are grouped together. Once we consider that environmental products

which are generated during production must be accounted for, then the sectoral aggregation must be changed. This is because -

- the scale of production may lead to different levels of emissions etc., and
- the technique of production (i.e., feed-stock and input uses and intensities) also affects the associated environmental consequences.

So, the household, unorganized and small-scale production sector must be treated separately. This informal sector is very important as it generates much of our GNP and employs many people.

Similarly, in conventional accounts, electricity generation may be one activity. Yet, electricity generation by hydro projects, coal, oil or gas generates different types and amounts of pollution. We may want to separate these activities.

The same argument also applies on the consumption side. Environmental changes also take place in the process of consumption. For example, when people travel by vehicles, air pollution takes place. The garbage and waste generated by consumers poses a problem of disposal. Even when people cook their food, the air gets polluted. Moreover, the environmental effects depend not only on the level of consumption but also on the mode and manner of consumption. Thus, travel by public transport causes less pollution than by private cars. Similarly, cooking with gas causes fewer emissions than cooking with wood or dung-cakes.

In addition to the sectoral disaggregation required due to scale and techniques of production, we also need to disaggregate some of the commodities represented by rows, particularly inputs provided by natural resources. For example, fuelwood, gathered wood such as lops and tops, and agricultural residues may be parts of agriculture or forestry rows in conventional accounts. These may now need to be separately accounted for as their use may have consequences for deforestation. These are also shown in Figure 2.2 as shaded rows and columns.

2.4 The Impact on Natural Resources

The effluents and emissions emitted as environmental joint products of different economic activities interact, spread, react and decay in different ways. In the end they change the state of various natural resources and assets. These

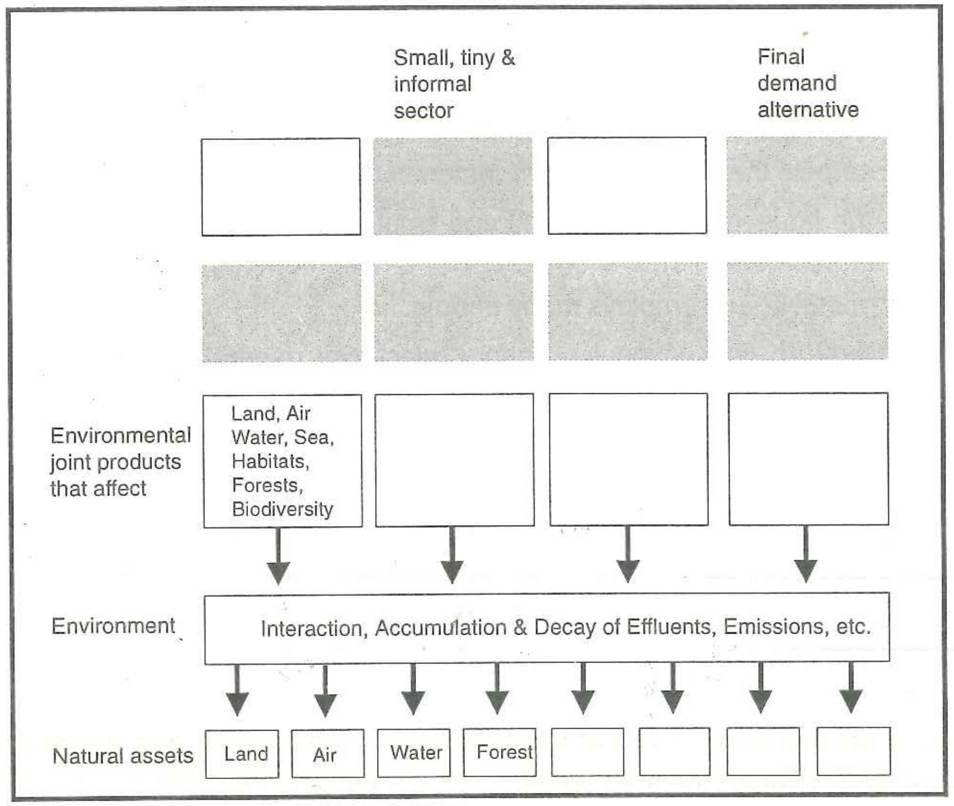

Figure 2.3: Extension of conventional national accounts for environmental accounting

changes along with the initial state of these assets give the state of these assets at the end of the accounting period. This is shown schematically in Figure 2.3. If we can value these various natural environmental assets in monetary terms, we can complete the first version of the IEEA by appending an account for the assets including natural assets of the society to the conventional SNA.

2.5. Valuation of Changes in Natural Assets

Once we have described the state of a natural resource and the changes it undergoes, what then? When should we be concerned about it? When do we consider the changes as acceptable? These are unavoidable questions. It is not possible to ask for a complete *status quo* or no change in the ecological

balance. For example, we cannot bring human population to a stationary state overnight, and the ecological balance must alter.

While one may agree to the need for valuation of natural assets, this task is not easy. Many assumptions and ethical judgements are necessary. Much research, discussion and consensus building are required. Nonetheless, to the extent possible, it would be worthwhile to assess the impact of economic activities and the changes in environmental assets brought about by these activities on human welfare of the present generation as well as the coming ones.

Thus, we complete the schematic framework of Figure 2.3 by extending it as shown in Figure 2.4.

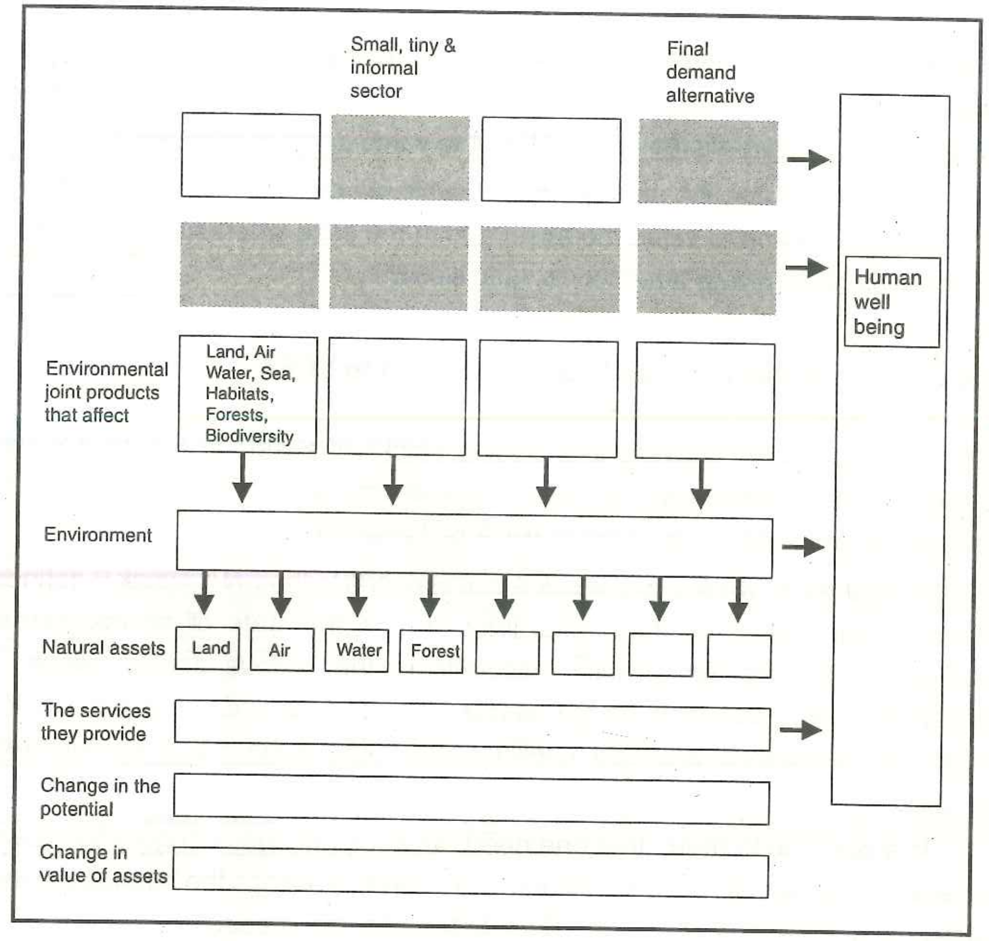

Figure 2.4: Extension of conventional national accounts for environmental accounting

It is to be noted here that we have recognized that human (and non-human) well-being is affected by the output of economic activities, the state of the environment and the services that the various environmental assets provide.

The first step in valuation is to identify the services that the various natural assets provide. For example, land can be used for cultivation, building a house, a playground etc. A change in quality that affects its suitability for a particular use can be utilized to assess the change in the value of the asset. Thus when land that is used as a farm becomes degraded, the farmer's income goes down. The present value of the stream of income loss is then the loss in the value of the land. Similarly, the location of a polluting industry next door can alter the value of a housing site as it is now less attractive.

Often a natural resource may provide a service that is not easy to value. For example, consider a playground in an urban area. The children using it, or their parents, may be too poor to pay for it, and their willingness to pay is a poor measure of its value. Loss of a playground is a loss that is not easy to measure. Another well-known example of a difficult to value asset is biodiversity.

Thus, identifying the services made available by natural assets is useful. It provides a means to value the asset and in the case when such a valuation is not possible, it draws attention to such services.

2.6 Comparing the Process Based Approach to SEEA

We can append the opening and closing stocks of assets to Figure 2.3 and obtain Figure 2.5 which gives an IEEA. It is quite obvious that this is conceptually almost the same as the concept of IEEA of Table 2.1.

In Figure 2.5, we see that Block A corresponds to the SNA. Block B defines the physical flow of environmental impacts and the state of environmental assets. These are the physical accounts of the various assets. Block C constitutes value accounts for the assets. The physical and value account for each natural asset constitutes a satellite account This is the critical new element in the IEEA.

It is possible to argue that one need not trace out completely all the flows of environmental effluents, emissions and effects to assess the changes in the state of environmental assets. The latter can be measured directly. For

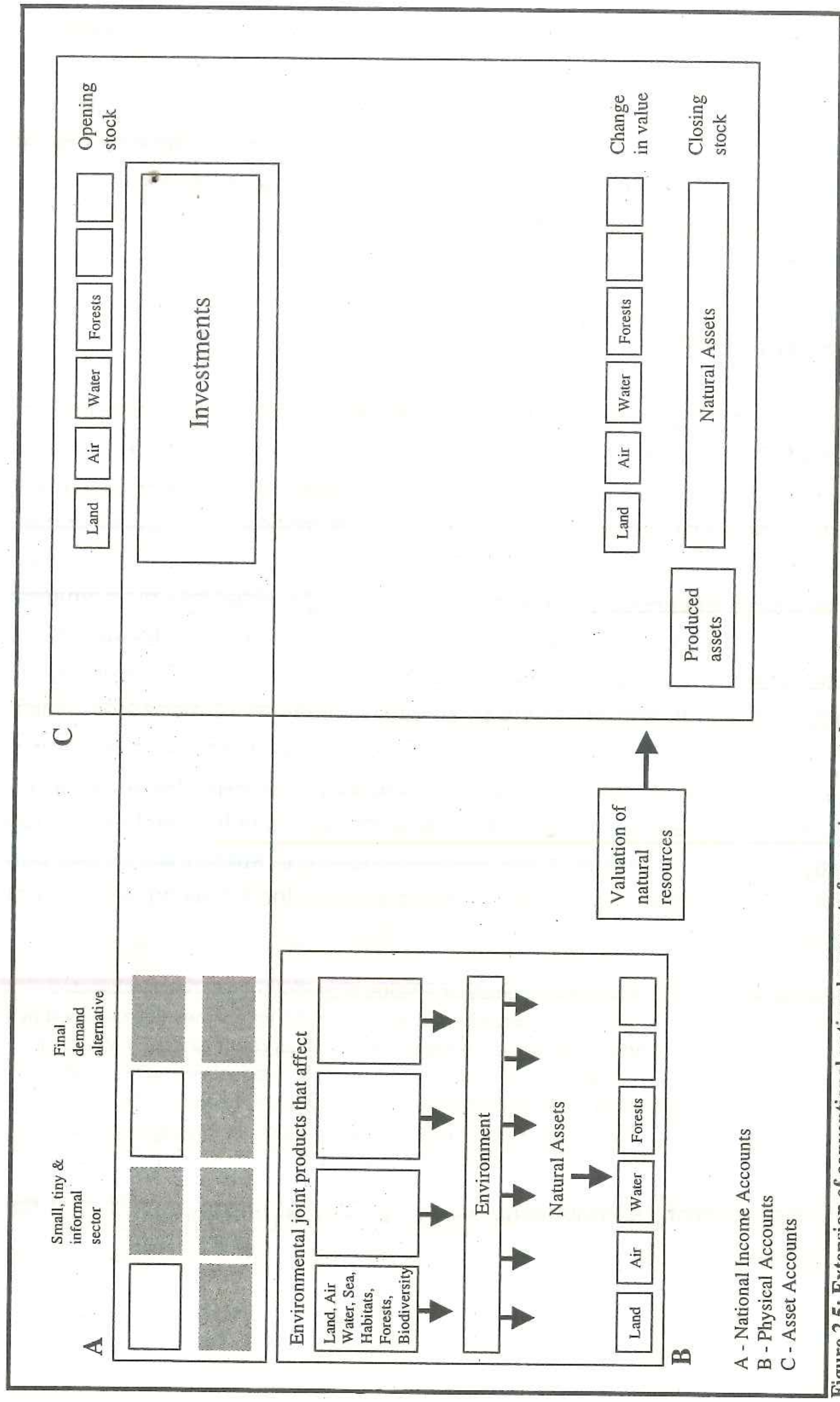

Figure 2.5: Extension of conventional national accounts for environmental accounting.

example, without knowing who emits how much of which emission, one can directly measure the ambient air quality and value the changes in that quality.

Thus, we will have to be pragmatic, depending on the data availability and purpose. In some cases, we may skip the physical processes and look only at the final state of the environmental resource and value the change in it. In other cases we may describe the physical accounts but may be unable to value it. In still others, we may be able to do neither.

2.7 The "Green NDP" — A Theoretical Definition

Our purpose in preparing an IEEA is to get an idea of our true net national product after accounting for depreciation of natural assets. Some refer to this as the green NDP, sustainable NDP or environmentally adjusted NDP (EANDP). Consider that social welfare depends on the consumption of produced goods, consumption of collected environmental products such as fuelwood from forests etc., enjoyment of various environmental amenities provided by environmental assets (such as clean air, clean water, scenic beauty etc.) and leisure. Also, consider that the quality of environmental services is affected adversely by production of goods and positively by defensive abatement measures, which require resources. Consider further that the quality of assets such as forests can be improved by human effort and worsened by over-exploitation. This is a slightly extended version of Dasgupta and Mäler (1995), in that we have added explicitly the value of leisure in the welfare function. In such a world, one can show that optimization over an infinite horizon gives the following definition of Net National Product:

Net National Product	=	Value of consumption + Value of productions of nature collected (such as fuelwood) + Value of environmental amenities provided by environmental resource stocks (such as clean air etc.) + Value of leisure enjoyed + Value of additions to productive capital + Value of additions to environmental resource stocks (clean air etc.) + Value of additions to natural capital stocks (such as forests) + Value of additions to stock of defensive capital.

In this equation, all valuations are to be done at prices prevailing at the optimal trajectory.

The important thing to note is that the so called defensive expenditures (such as medical expenditure needed to fight the effect of pollution) are not deducted here and that the value of environmental amenities are added as recommended by Peskin (1989). Both these approaches differ from that of the United Nations Statistics Division (UNSD). However, the UNSD approach does not assume that the economy is on the optimal path (if it were so then perhaps the need for an IEEA would not have arisen). Nonetheless, one needs to carefully understand what it is that one is trying to measure.

One should also note that deduction of defensive expenditures at the level of a satellite account may be justified. Consider, for example, a power plant emitting particulate matter into the air. This may make some people sick causing them to spend money on medicines and miss work. Their loss in income may already be included in the conventional national accounts as less output of sectors in which they work. However, if we are to judge the power plant, this loss in income should be shown as a negative outcome of this plant. A satellite account is like the account of one division of a firm. To judge its performance, its borrowings from other divisions of the firms must be taken into account. One has to be careful, however, when integrating the accounts of different divisions of the firm to obtain its aggregate profit and loss position and ensure that no double counting takes place.

Thus, up to the level of satellite accounts there is no fundamental conceptual difference among the various proposed approaches to IEEA. The differences arise at the level of final adjustment of the NDP to obtain the green NDP.

However, even at the level of satellite accounts, the approaches to valuation may differ. Here the choice of approach is often determined by availability of data. First, it is useful to understand what it is that one ought to measure so that one can assess whether a particular valuation approach gives a lower bound or an upper bound on the value. This we examine now with the help of Figure 2.6.

In Figure 2.6 we consider emission of a pollutant such as suspended particulate matter (SPM) in air. The level of emissions is plotted on the *x*-axis (one could also look at it from right to left as increasing air quality considering E as the origin).

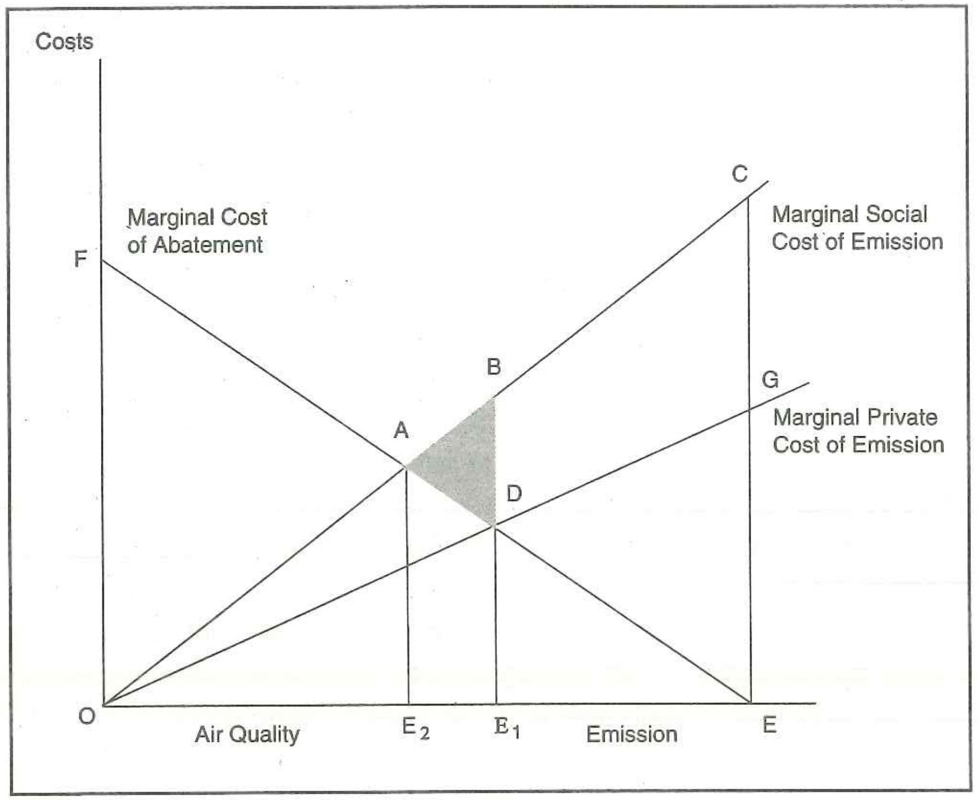

Figure 2.6: Demand and supply of air quality and optimal emission level

The line FE shows the marginal cost of abatement (MCA) that would have to be incurred if the emissions were to be reduced. At point O, abatement is complete and there is no emission. The total cost of this abatement would be the area under the line FE, namely the area FOE. If emissions are to be restricted to level OE_1, i.e., if abatement is to be done to the extent of EE_1 the cost of abatement would be area DE_1E. The line FE reflects the engineering or technological costs of abatement.

The line OC in the figure shows the marginal social cost of emission. These are the costs borne by society due to the emission. For example, suspended particulate matter (SPM) laden air may aggravate respiratory diseases. The incidence of morbidity (sickness) may go up and mortality may also increase as additional deaths are caused by it. There may also be other costs: visibility may be reduced, leading to more accidents or closure of airports, buildings may

become dirtier, thus increasing the costs of maintenance and repainting, property value may go down and so on. The line OC reflects these costs. In a sense, this is what those who suffer from this pollution may be willing to pay to reduce the level of pollution. Thus, if the pollution is to be restricted to the level OE_1, the society should be willing to pay an amount equal to the area CEE_1B.

The third line OG shows the private cost of emission to the emitter herself. For example, if there is an emission tax the rate of which increases linearly with the level of emission then OG will represent the marginal tax rate. It is also possible that the emitter herself suffers from the emission. This can happen, for example, if SPM emission by a plant clogs up its own machines and reduces the efficiency of its production processes. In this case, the polluter saves the abatement cost FOE by not doing any abatement but bears the cost OGE, because of the emission OE. It is obvious that the polluter would minimize her costs by abating up to level E_1 so that the total costs borne would be equal to the area ODE.

By imposing a rising tax on emission we internalize the social cost of emission for the emitter, i.e., these costs now become a part of, internal to, her profit and loss account. If the level of taxes correspond to the line OC, then the social costs are completely internalized. If tax rates correspond to OG, the social costs are only partially internalized. The level of emission would depend on the extent to which costs are internalized. Thus, it would be observed that

OE_2 = Optimal level of emissions, when social costs are completely internalized.

OE_1 = Emission if some costs are internalized.

OE = Emission when no costs are internalized.

From the point of view of valuation we should note the following:

If you observe OE, and take the area OFE as the cost of abatement and hence as the value of loss of air quality it may be an overestimate or an underestimate depending on whether the area OCE is smaller or larger than the area OFE.

- If you take OCE as the cost that may also be an overestimate (or underestimate).
- What you really want to estimate is area ABD which is the loss to society.

However, for this you need to know the optimal emission E_2.

It is useful to keep this diagram in mind in deciding what we are measuring with different techniques of valuation and what we want to measure.

2.8 Valuation — The Critical Step

The framework outlined can be implemented if we can value changes in the various resources. We deal with how to do this in subsequent chapters. We first look at some techniques of valuation in the next chapter. Then in the subsequent chapter we specifically examine how to value exhaustible resources, land, produced natural assets such as forests and non-produced natural assets such as air, water etc.

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3

Methodological Approaches to Valuation

3.1 Need for Valuation and Difficulties

Physical accounts discussed so far are relatively easier to handle because the engineers and plant managers can tell us how much water, fuel and other resources are needed to produce, say, one tonne of steel or cement or fertilizer. However, it is not enough to leave these accounts in physical terms because pollution from steel or coal cannot be added if they occur at two different places. We can only add the damages in monetary terms either as national damages or abatement costs incurred. However, degradation and depletion or restoration and regeneration cannot be always valued through market transactions. This is so because, unlike material artefacts, environmental amenities (clean air, unpolluted beaches etc.) are seldom bought and sold in the market. As a result, there is no comparable estimate of the *value* of environmental amenities. Decisions on resource utilization, degradation of amenities and resource allocation are often made without any estimate of the value of the amenity in question. In such situations, it is observed that the resource goes unpriced; environmental amenities are often either ignored or treated as having zero value.

Economic valuation of environmental resources (and consequently their degradation) can help make decisions on resource utilization and allocation more meaningful. For example, consider an air polluting industry. If the economic value of air quality degradation can be incorporated into the cost benefit analysis, the resultant conclusions will be more holistic and comprehensive compared to those from an analysis which treats clean air as a *free* resource.

Yet another important application of economic valuation of environmental degradation is relevant for decision making. Economic valuation helps prioritize decisions regarding sectoral resource allocation designed to improve environmental quality. While the pollution of beaches by sewage may be the most obvious environmental problem in a city, the increased incidence of respiratory diseases consequent to air pollution may be also significant. Unless a proper economic analysis is conducted, *a priori* decisions would most likelv

be made to invest precious resources in improving beaches and sewage treatment rather than air quality. Economic valuation helps prevent such inefficient, *a priori* decision-making.

In short, economic valuation of resources needs to be undertaken when the markets fail to generate the true price of the resource in question. Market failure leads to sub-optimal tapping of the resource, and society must pay for this tendency. An economic valuation helps compute the true price of a resource, so that decision-makers can make informed choices, and society need not lose out on welfare.

Market failures are common for environmental resources. Externalities and diffused and undefined property rights lead to such failures. The same problems also pose difficulties in valuation. The impact of environmental degradation may be borne by people far away or by future generations. Such is the case with greenhouse gas emissions. Intergenerational issues complicate the valuation problem further. How much weight to give to tomorrow compared to today is not a difficult problem. How much weight to give to future generations is a much more complex issue.

Once we go beyond anthropocentrism, the valuation problems become issues of deep philosophy. How much is biodiversity worth? What is the value of a habitat that is vital for the survival of some non-human species? What is the value of a pond or a lake or a pasture to the community? And finally, how do we value illness, loss of IQ (Intelligence Quotient) and even deaths that result from pollution? What is the value of human life?

Our purpose here is a much more modest and limited one. Some environmental resources can be valued from the limited anthropocentric perception. Such valuation can help improve the rationality of human actions. We examine here methods of such valuation.

3.2 Overview of Methods for Environmental Valuation

Having established the importance of economic valuation and its utility, let us now turn to the tools used for valuing environmental amenities. A variety of economic techniques and models have been developed for assigning monetary values to gains or losses associated with changes in the availability (quantity) or character (quality) of environmental amenities. The aim of these techniques is to obtain an estimate of the value of an environmental amenity that would be revealed if there were a competitive market for the amenity. Figure 3.1 shows that the changes can be deduced either directly or indirectly.

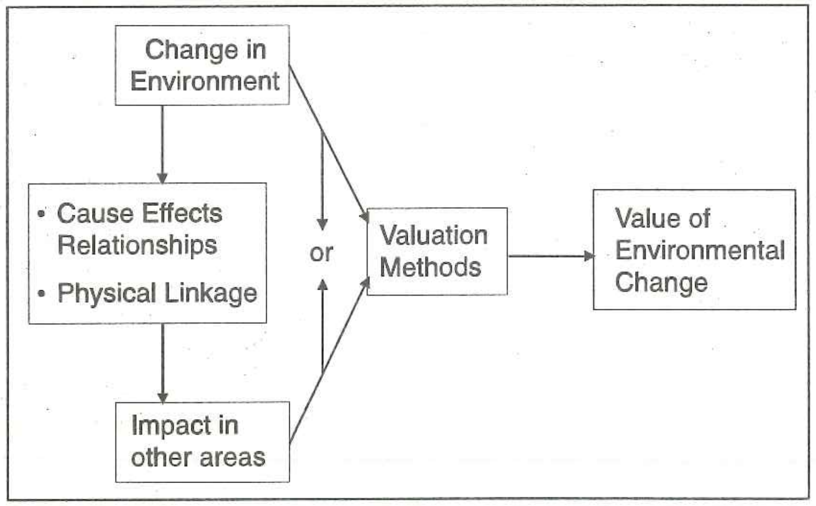

Fig 3.1: Steps in valuation

Valuation methods can be classified as shown in Figure 3.2. For simplicity, we classify them into three categories:

(a) Physical linkage methods (scientific): They require assessment of loss in production, income or health. Thus, these can be valued as financial transactions.

(b) Abatement cost methods (technical).

(c) Behaviour linkage methods (economic).

3.2.1 Physical linkage methods

These methods are termed *scientific* by us or *objective* by Dixon and others, (1994) because they depend on a causal connection between environmental change and its effects on other objects - processes, products or persons. In the physical linkage approach, environmental values are estimated by establishing relationships between the physical effects of some environmental change on some other factors such as human health, productivity or earnings. One may also need to assess the impact of pollution on ecosystems, on productivity of a

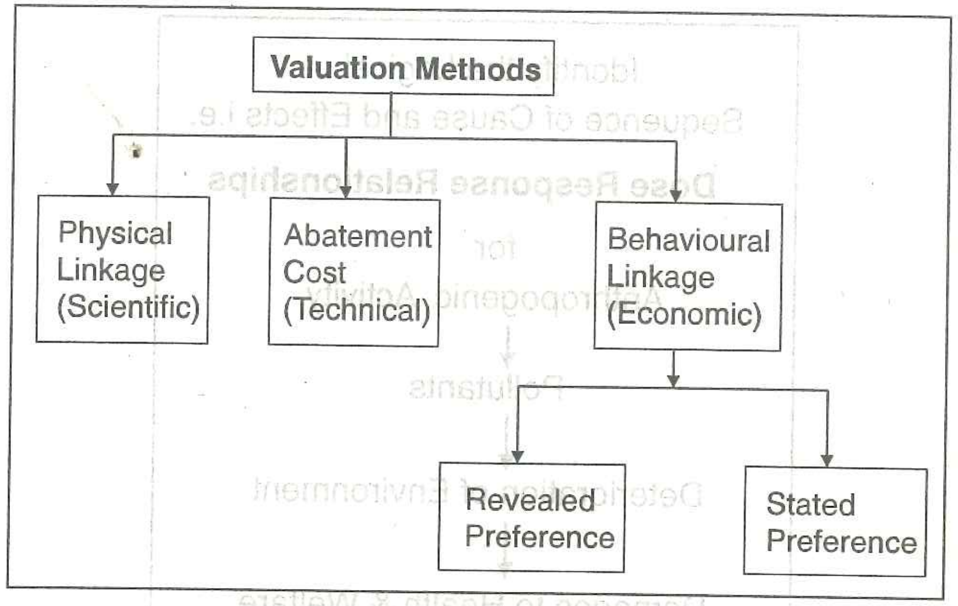

Figure 3.2: Valuation methods

fishery, or depreciation of a physical asset. Once this is done, we quantify these impacts and then value them to arrive at the value of environmental changes. The physical linkage approach is also known as the damage cost or dose-response approach (refer Figure 3.3). The objective is to measure the changes in net benefits as revealed in physical terms or market prices caused by environmental damage. Alternatively, benefits can be measured as the increased productivity due to improved environmental quality. The relationships can in principle be objectively determined based upon scientific observations (Shin and others, 1993).

3.2.2 The abatement cost methods

The abatement cost methods approach the problem of valuation from the supply angle as opposed to the other two methods, which approach it from the point of view of demand for environmental amenity. The former are termed technological methods or an emerging approach because they are based on the view that the costs required to abate the pollution would estimate the value of damage. This method is also known as the *maintenance cost* method as this

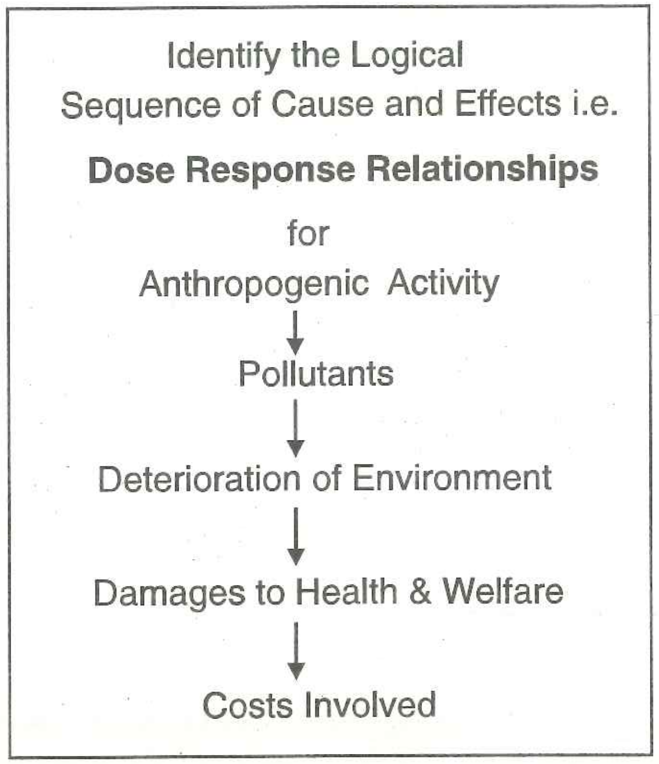

Figure 3.3: Physical linkage method

cost would maintain the environmental quality at a constant level. For example, one can install electrostatic suspended precipitators to remove suspended particulate matter (SPM) from a boiler or a furnace, or use a desulphurization process to remove sulphur oxides (SO_X). Then the value of the damage due to a tonne of SPM can be derived as the cost of removing one tonne of SPM. For this purpose, the capital cost of the abatement equipment is annualized over the life time of the equipment and the annual variable cost is added to that. In a developed country, where pollution control is likely to be stringent, the marginal cost of abatement is likely to be nearly equal to the marginal social cost. One can therefore use abatement cost as a proxy for social cost. However, in the developing countries, this does not apply. Very often social costs far exceed the abatement costs and yet nothing is done. Thus, the approach should be that the abatement cost approach should be used only if the abatement costs

have actually been incurred. Otherwise the damages experienced by society - in the absence of abatement measures - should be worked out.

3.2.3 Behaviour linkage methods

Valuation techniques in general assume that the value of environmental goods should be based on peoples willingness to pay (WTP) to secure better environmental quality or to escape environmental deterioration. These techniques to estimate behavioural parameters can be further classified depending upon whether preferences are revealed in the market place or stated in a survey.

In the revealed preference methods the value of an environmental amenity is estimated indirectly from the purchase price of a commodity whose market value at least partly depends upon the quality of the environmental amenity in question. The value of an unpriced amenity is inferred by using statistical analysis to examine how a change in the amenity affects the observed purchase price of related private goods. For example, in the hedonic price approach, a preference shown for environmental amenities is reflected in the price. Thus, people are willing to pay a higher price for a house located on a beach, next to a park or, in a quiet area. Therefore, real estate values can be examined to detect any premium paid for a location with the desired amenity (Streeting, 1990). The premium can be taken to reflect the value of the amenity.

Stated preference methods and contingent valuations assume that people respond to hypothetical market situations as if there were actual markets. The methods rely upon what people *say* they would buy, if the market existed. In a contingent valuation survey, respondents are presented with an opportunity to express their willingness to pay (or willingness to accept compensation) for a change in the level of environmental amenity benefits (Wilks, 1990).

The selection of a certain technique for a certain purpose is a matter of judgment as there are no standard prescriptions. The choice of a method for a given problem is a function of data availability, time, budgetary constraints and the intended end use of the results. Physical linkage methods can only be used when scientific relationships establishing such physical linkages are available. Contingent valuation methods can be employed for valuing any sector of the environment but the accuracy will vary greatly depending upon the administration of the survey, how representative the sample population is, the description of the damage caused by environmental degradation, etc.

The use of one or more of the above described techniques of economic valuation calls for an extensive search for data and a scrupulous examination of available statistics. A judicious valuation of available methods *vis-a-vis* available data needs to be made to arrive at a reasonable conclusion regarding the appropriate method for the project in question. Further, one may have to use a combination of techniques in different environmental sectors for the economic evaluation. For example, physical linkage methods may be more appropriate for damages caused to human health due to air pollution whereas stated preference may be more appropriate for eliciting how much people value a national park. In addition, the synergistic effects of many environmental components acting in tandem also need to be understood before attempting to determine which method is appropriate. Having overviewed the methods briefly, we discuss each in detail.

3.3 Physical Linkage Methods

Physical linkage methods are valuation methods that first establish cause-effect or dose-response relationships and then value the impacts of environmental

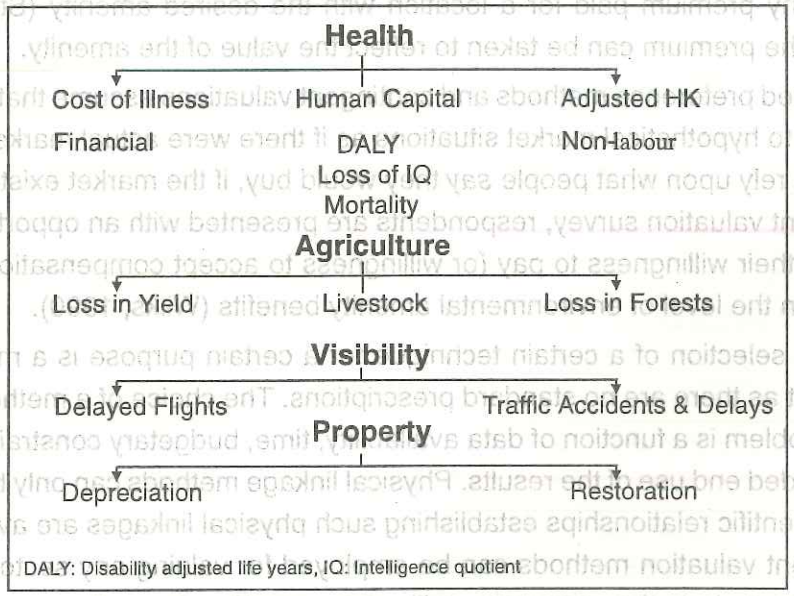

Figure 3.3: Physical linkage method

change to reflect the value of environmental change. As stated earlier, the first stage is to identify the logical sequences of cause-effect relationships, with regard to the deterioration of an environmental attribute and its impact on human health and welfare (Hufschmidt and others, 1983).

The estimation of the cost of the environmental degradation does not require a complete understanding of all links in the logical chain (Shin and others, 1993). Information on the quality of an environmental component defined as some parameter (e.g., air quality as SPM concentration) and the resulting incremental incidence of an adverse impact (e.g., excess respiratory diseases), may be sufficient to obtain a first estimate. Once these relationships are determined and confirmed, one could estimate the cost of quality degradation.

The practical utility of such estimates, especially for policy conclusions, often depends upon a comprehensive understanding of the events leading to a deterioration in the quality of the environment.

The procedure for estimating health and productivity effects involves three steps. The first step is to determine the relationship between changes in exposure to environmental pollution, for example, human health as measured by mortality and morbidity rates. The second step is to use this relationship to predict the changes in mortality and morbidity associated with specific changes in environmental pollution and exposure to pollutants. The third step is to derive monetary measures of changes in health status.

The first task in the physical linkage method is to arrive at a suitable dose response function. For human health, this is derived through a combination of biomedical studies and statistical analysis. Damage functions could be either on mortality or on morbidity. Those specified by Lave and Seskin (1977), focused mainly on mortality, while Ostro (1983, 1987) and Krupnic and others, (1990) concentrated on morbidity effects. These studies seem to provide credible and consistent results. For example, Lave and Seskin (1977) estimated the elasticities between mortality and degrees of sulfates and particulates pollution. The estimates of elasticities across different data sets, model specifications and degrees of desegregation were substantially similar within the range of 0.09 to 0.12. That means that a 1 per cent increase in pollutant concentration will increase the mortality rate by about 0.1 per cent. Similarly, Ostro (1983, 1987), estimated the effect of air pollutants on morbidity using damage functions. Restricted activity days (RAD) and work loss days (WLD) were regressed to particulates, sulfates and several socio-economic variables. The regression results showed that particulates affect both RAD and WLD significantly. The elasticity was 0.45 for WLD and 0.39 for RAD.

The estimation of mortality or morbidity effects requires sorting out the effects from many confounding factors such as genetic factors and lifestyle differences. In developing countries there is an additional problem. The longevity and health status of people are on the rise, on the average, as a result of a number of factors like better public health facilities, improvement in quality of life and improved medical facilities. Pollution levels have also been rising. To arrive at a figure of excess mortality within an overall trend of diminishing mortality poses an exceedingly tricky statistical exercise.

The physical linkage methods can also be used to establish the loss of productivity of agricultural yields, fishery or livestock or even loss in visibility and its impact on traffic accidents and delayed flights. These also pose complex statistical problems of estimating response functions. One would need to face them or find shortcuts. This will be further elaborated in the next chapter.

3.3.1 Cost of illness

The cost of illness (COI) approach measures the cost of environmental damage in terms of direct outlays for the treatment of illness (hospital care, cost of medicines, cost of the services of physicians and other medical personnel) plus indirect losses in output due to illness measured by the social cost of lost earnings (Rezeler, 1993).

The cost of illness approach does not account for the expenditure incurred by the individual to avert illness. The value of personal pain, suffering and inconvenience associated with illness is also not taken into consideration. Cropper and Freeman (1990) suggested that society's willingness to pay to reduce the health risk should also be added to get the full social costs of illness. The application of COI in a developing country like India is limited by two factors:

A great number of people affected by diseases do not approach hospitals for lack of awareness, accessibility and affordability.

The entire health care system is heavily subsidized, and hence an estimate based on actual expenditure will be far below the true expenditure and associated opportunity cost.

Nevertheless as a lower bound, cost of illness is quite an appropriate measure of actual illness-related expenditures.

The application of physical linkage methods faces severe difficulties encountered in convincingly proving the cause-effect relationships. For example, in the case of air pollution, it may not be really possible to establish that the increase in incidence of bronchitis is a function of increase in sulphur dioxide concentration in the ambient air. While such a medical relationship might indeed exist, it can always be questioned on counts of synergistic effects. In a locality where there is both high SO_2 and high SPM, an increase in respiratory diseases cannot be exclusively attributed to either sulphur dioxide or SPM. Computing the economic cost is even more complicated when one has to establish a numerical relationship between levels of a pollutant and the incidence of a certain disease. Different pollutants and their various combinations cause a variety of diseases; to establish a convincing numerical link between given levels of pollutants and loss of human capital as a consequence is (to say the least) statistically arduous.

There are however possible ways of arriving at reasonable policy conclusions using physical linkage methods by making some simple assumptions. Consider the example of air pollution. The first task is to identify the dominant pollutant in a given city. A dominant pollutant can be defined as one which has demonstrated health effects (supported by medical literature) and is widely prevalent and increasing at a rate faster than other pollutants in the city. Once we have identified dominant pollutants, we could take these pollutants in isolation and estimate the health damages due to them. By a careful selection of the dominant pollutant, we can obtain a reasonable lower bound on the estimate of environmental degradation.

3.3.2 Human capital approach

It is not enough to account for expenditure on illness. Illness and disability - temporary or permanent -have private and social costs that need to be accounted for. The human capital (HK) approach for valuing morbidity assumes that the value of an individual is the potential of *production* the person possesses. Once the damage function is obtained, the essential factor is the unit economic value of the physical damage (mortality/morbidity). A product of the numerical values of both the number of people affected or dead and the unit cost of treatment or death will provide the monetary value of health damages (OECD, 1989). It is therefore, important to arrive at numerical values for the value of statistical life as well as the cost of WLD/RAD consequent to morbidity and mortality. The following methodologies to arrive at such values have been used.

According to Mishan (1982), the present value of a person's expected future earnings may be calculated as

$$L_1 = \sum_{t=j}^{\infty} \frac{Y_t P_j^t}{(l+r)^{t-j}}$$

where Y_t = the expected gross earnings of the person in the t^{th} year; P_j = the probability in year j of the person being alive during the year t and r = the social rate of discount expected to prevail during the year t.

Alternatively the net income can be specified by subtracting C_t, the individual's expected expenditure during the year t, from Y_t.

Among the drawbacks of the HK approach are the following:

(a) Non market productivity is usually excluded from the valuation. Thus, persons not getting a stream of income for their services have zero economic value. For example, work within the household by women and children is not included.

(b) Other dimensions of illness and death such as pain, suffering, aversion to risk, loss of leisure and adverse effects to others are not included (Dalvi, 1988).

(c) The final values thus generated are very sensitive to the selection of an appropriate social discount rate

The adjusted HK approach addresses some of these problems. It calculates the value of human capital as follows:

$$L_1 = \left[\sum_{t=j}^{T} \frac{Y_t}{(l+r)^t}\right] \alpha$$

where T = the remaining life time; Y_t = after tax labour and non-labour income; r = individual's opportunity cost of investing in risk reducing activities; and α = a risk aversion factor. Both r and α are assumed to remain constant over time.

This method also fails to account for intangibles like pain and suffering. It is suggested that the adjusted HK method is the most appropriate method for evaluating environmental policies that involve risk to human life.

In the event that deaths occur due to pollution, human life has to be valued beyond the *cost of illness* and disability adjustments. It should be emphasized that here a specific person's life is not valued; that value is always infinite to himself/herself and the relatives. Statistical value of life is a concept that captures the payments made either by insurance companies or workmens compensation acts, compensation awarded by courts and so on.

3.3.3 Statistical value of life

An alternative method of approaching the delicate question of valuing human life is to analyze the behaviour of people in paying for reduction in risk to their life or accepting compensation for undertaking risky jobs. The willingness to accept compensation for one's life will be meaningless because the money is of no use without life. However, in valuing the impact of environmental degradation on mortality, we are not analyzing the value of a specific person's life but rather the value of a statistical life. Compensating wage differentials for risky jobs can be used to estimate an individual's willingness to accept money for a change in risk of death. The underlying assumption is that workers will accept risk up to the point where the marginal benefit of compensation is equal to the marginal cost of taking risky jobs. A risk premium is obtained by the partial derivative of the wage function with respect to risk, where the wage function is specified in terms of job characteristics and factors affecting workers productivity.

The aversive behaviour (or defensive expenditure) approach infers the value of risk-reduction from the observation of people's voluntary purchase of certain risk-reducing goods or avertive consumption behaviour. According to this approach, people use life-saving consumer goods such as seat belts or smoke detectors until the marginal cost is equal to the benefit of reducing the probability of death. This avertive expenditure is an approximation of individual WTP to

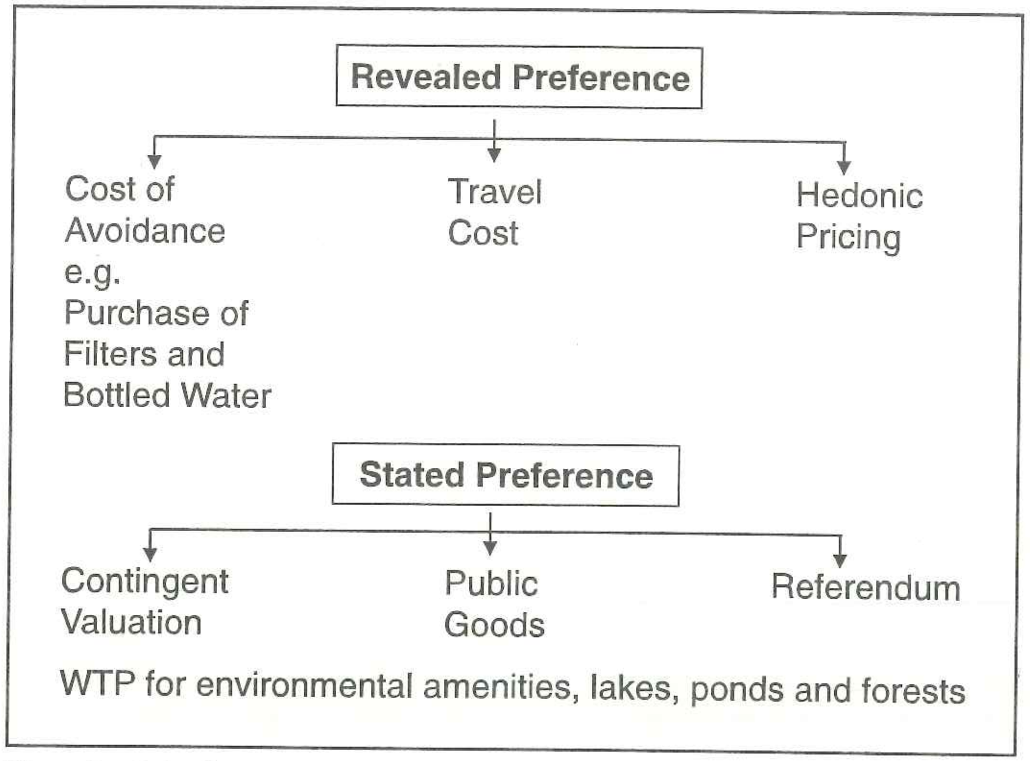

Figure 3.5: Behaviour linkage method

avoid risk (Gerking and Stanley, 1986). By dividing the annual cost of avertive behaviour by the reduced risk of death (illness), we can estimate the value of life or loss of time (Blomquist, 1979).

The approach assumes that the labour market is free and is in equilibrium, that the workers perceive the risk correctly, and most importantly that the workers have a range of choices from which to choose. In addition to the obvious violations of these assumptions in most real life situations, there are further objections to the application of this method for calculations in environmental economics:

- The wage differential is for a voluntary risk whereas risks associated with environmental degradation are involuntary.
- The wage differential relates to compensation received for an increase in risk over the normal risk.

3.4 Behaviour Linkage Methods

Here we assume that the value of environmental goods and services is based on people's willingness to pay to serve them or to avoid the impacts of degradation. These preferences may be merely stated or revealed directly or indirectly. Examples of revealed preference for a resort or clean water are how much people pay to go to the resort or to buy water filter?

3.4.1 Revealed preference methods

These methods are based on actual information revealed in the marketplace.

Travel cost method : The travel cost method (TCM) is widely used to estimate amenity values for outdoor recreation sites (United States Water Resources Council, 1979). The basic philosophy of this method is to use the cost of travel as a surrogate for the willingness to pay for using the recreation site. Travel costs could include actual transportation cost, fees paid at hotels and at times the opportunity cost of travel time spent on the journey. People staying far from the site will be paying a higher travel cost as compared to those who stay nearby and accordingly, the visitation rate of the former will be smaller than the latter.

The first step in applying the TCM is to collect data through a visitor questionnaire at the site. The list of required data includes transportation expenditure, hotel expenses and park entrance fees, the amount of time spent on travelling, and various socioeconomic characteristics of visitors. In the case of economic approaches, the second step is to derive an equation that relates the visitation rate and the independent variables which affect the visitation. Examples of these variables include the total travel cost of visitors and their income, age or other socioeconomic characteristics. The third step is to construct a system of demand equations to get an aggregate demand curve for the site. The last step is to measure the area under the aggregate demand curve to get the benefit visitors enjoy from the recreation site.

The travel cost of visiting the resorts may not be easy to capture. The visit to the resort may be combined with other visits and there may be other reasons for travel. For example, the travel cost associated with commuting for those who prefer to live in far away, cleaner areas may be considered an expenditure to avoid air pollution. However, the resident may also be paying for a larger house in the suburbs, and not only to avoid pollution. Thus, the TCM valuation procedure also involves statistical complications. Moreover, TCM requires substantial effort to get primary as well as secondary data, and is applicable less to urban degradation than to amenities such as national parks or resorts.

The hedonic pricing method : The hedonic pricing technique uses a related market approach to obtain the value of an environmental amenity from indirect observations (Rosen, 1974). The basic premise is that for many environmental goods, it is often possible for individuals to choose their level of consumption through their choice of related market goods. For example, in the decision to purchase a house in a residential area, one could choose the levels of noise, air quality, water supply and sanitation facilities etc. (Anderson and Crocker, 1971; Wieand, 1973; Schnare, 1976). The value of an apartment facing the sea may be higher than that of a same size apartment facing away from it. Such differences in prices may be attributed to the value of enjoying the sea view.

In a decision to buy a family home, there is an implicit market in environmental quality, and the demand for non-market environmental goods such as air and noise pollution contribute to the observed prices and consumption of market goods (i.e., houses in this case). For example, the typical preference for living in quieter residential areas might be reflected in the willingness to pay more for a house that is not adjoining a major freeway or an airport (Burns, 1989; Nelson, 1980; among others). This rationale led to the development of the hedonic pricing technique as a means of describing valuations of non-market environmental goods.

In essence, the hedonic pricing method employs statistical techniques to isolate environmental values which contribute to an observed difference in product prices. Typically, the composition of real estate values have been analyzed to draw out these environmental values (Streeting, 1990).

The key initial task of the hedonic price technique is estimating the implicit price function (Streeting, 1990). The construction of the implicit price function

is based on the idea that goods and services are composed of a number of attributes and that the relative amounts of these attributes contribute to the total value of any particular good. For example, in the housing market, the price of a house is related to structural aspects, Reinforced Cement Concrete (RCC) (RCC/wooden/pre-cast, etc.) and physical attributes (living area, number of bed rooms etc.) locational and neighbourhood characteristics (shopping centres, school quality, population density etc), together with environmental features (air and noise pollution etc.). In this sense, the value of each attribute is implicit, or reflected in the total house price.

In mathematical terms, the generalized form of the implicit price function can be expressed as follows:

$$P = F(X_1, \ldots, X_n) \tag{3.1}$$

where P is the price of the product under consideration and X_1 to X_n are the attributes of the product.

Regression analysis is used to estimate this equation (3.1) and the coefficients of each of the independent variables (X_1 .... X_n) represent the implicit prices for each of the attributes. This then enables the price differential within the product class (P) to be assigned quantitatively to each attribute.

3.4.2 Stated preference methods

These methods are not as direct as revealed preference methods. Among these is the contingent valuation (CV) method which we now describe.

Contingent valuation methods : In many respects, CV is similar to market research surveys that estimate consumer demand for a new product. The CV method uses surveys to elicit people's valuation of increases or decreases in the provision of environmental amenities by constructing a hypothetical market. This market is outlined to the respondent in a scenario describing the amenity, the actual or likely change in provision of the amenity, the organization providing the amenity and the method of payment. Respondents are then asked for their valuation, contingent on the scenario described to them.

In a CV survey, individuals may also be asked about their attitudes, expectations, needs and opinions related to the amenity in question. These supplementary questions provide useful insights into the attitudes and behaviour of different people with respect to the environment. In most applications, the CV procedure involves asking people what they are willing to pay for an environmental benefit, or what they are willing to accept for an environmental "loss". The aim is to reveal the price at which the respondent is no longer willing to purchase the environmental amenity, thereby revealing the individuals maximum willingness to pay. CV can also be applied to reveal a potential loss by asking people what they are willing to accept by way of compensation for environmental degradation or loss of environmental amenity (Imber and others, 1991). However, questionnaires asking how much people will pay to acquire a benefit do not necessarily yield the same as similar questionnaires asking the amount of compensation demanded to give up the benefit (Knetsch, 1993).

CV surveys can be administered by personal interviews, over the telephone or by mail. There is no specific method of survey administration that is always preferred. The advantage of personal interviewing is that the interviewer can carefully probe the respondent, repeat questions or use visual aids to clarify any ambiguous response. The questions can be put in a sequence, which cannot be ensured in a mail survey. However, it is expensive to have personal interviewers for large samples. An ill-trained interviewer can do more harm than an improperly designed questionnaire. Because of these, it is often necessary to resort to telephonic or mail surveys or else train the interviewer very carefully.

CV surveys can replicate either a private goods market or a referendum to obtain benefit estimates. The advantages and limitations of the two models are briefly reviewed below.

Private goods market model : In a private goods market model, a scenario is usually described to the respondent where the opportunity to obtain the benefits of amenities is offered at a range of prices. This model is best suited to quasi-private goods such as access to beaches, fishing rights or any other amenity, where a permit to access (to the exclusion of others) is feasible. Application of this model to public environmental amenities, such as clean air, tend to be less successful as the procedure usually requires the respondents

Table 3.1: Comparison of contingent valuation method (CVM) with other techniques

CVM results		Indirect market study	
Commodity	**Value[a]**	**Method**	**Value[a]**
Recreation days	$1.71 per household/day	Travel cost method (TCM)	$1.66 per household/day
Hunting permits	$21 per permit	TCM	
		value of time = 0	$11.00
		value of time = 1/4 median inc.	$28.00
		value of time = 1/2 median inc.	$45.00
Water quality improvements	User values:[b] average (across question format)	TCM	User values
(a) loss of use	$21.41		$82.65
(b) boatable to fishable	$12.26		$7.01
(c) boatable to swimmable	$29.64		$14.71
Boat permit to:	Close-ended consumer surplus:	TCM	Consumer surplus
Lake Conroe	$39.38		$32.06
Lake Livingston	$35.21		$102.09
Lake Houston	$13.01		$13.81
Recreation site	Population value per household per day: $2.54	Site substitution	Population value per household per day: $2.04
Air-quality improvements:	Monthly value[c]	Hedonic pricing method (HPM) (property values)	Monthly value:
(a) poor to fair	$14.54		$45.92
(b) fair to good	$20.31		$59.09
Municipal infrastructure in:	Elasticity of substitution of wages for infrastructure	HPM (wages)	Elasticity of substitution of wages for infrastructure;
(a) Grants	NM	-0.037	
(b) Farmington, NM	-0.040		-0.035
(c) Sheridan, WY	-0.042		
Natural hazards (earthquakes) information	$47 per month	HPM (property values)	$37 per month

Source: Cummings, Brookshire and Schulze (1986), p. 125.
a Mean values amongst respondents.
b Values apply to post-iteration bids for users of the recreation sites.
c Value for sample population.

to imagine that they can own and use the amenity to the exclusion of other persons.

The elicitation method often used in the private goods model is a bidding game technique designed to resemble an auction. The interviewer raises or lowers the bid until the respondent decides to make a purchase, thereby revealing his maximum willingness to pay. In an open-ended question, the opening bid or the final valuation can be stated by the respondent without any prompting. In a closed-ended format, respondents are asked to answer "yes" or "no" to a proposed payment.

The referendum method : In the referendum method, respondents are asked whether they would be willing to pay or sacrifice a specific amount of money in order to preserve the environmental amenity in question. A referendum can also be held about a specific action, where there is a discrete choice, and the answer can only be *yes* or *no*. A range of amounts are put to a number of subsamples. The referendum model can be used to elicit respondents' votes on a tax level or the tax rate for the provision of a public amenity. It has been extensively used in the developed countries. For example, in Austria a nuclear power plant already built at Zwentendorf was mothballed following a referendum. The value of foregone benefits and additional expenses for alternative electricity could be considered as the cost of avoiding risks of nuclear power.

Willingness to pay/accept from CV studies : Once the survey responses are available, obtaining the numerical value of willingness to pay/willingness to accept (WTP/WTA) is rather easy. One could either take the mean or the median value of the reported WTP/WTA. There is however, no norm about whether means or medians should be used. While the median has been the preferred mode in the referendum model, experts have questioned the validity of this practice. Haneman (1991) has suggested that the choice between mean and median be derived from a prior choice of a social welfare criterion.

How acceptable are contingent valuation techniques? While an influential report of a blue-ribbon committee having among its members two Nobel prize-winning economists (Arrow, and others, 1993) guardedly approved the CV approach, if it is done correctly and certain conditions are met, other mainstream economists remain sceptical. Nonetheless environmental

economists have used CV methods and in some cases some comparisons with conventional valuation methods are also available. Table 3.1 from Cummings, Brookshire and Schulze (1986) shows that the CV results give estimates which are comparable to those from other methods.

3.5 Concluding Comments

A variety of valuation techniques are needed to value environmental change. In applying many of these, some shortcuts and simplifying assumptions would be unavoidable. In making these assumptions, however, one should keep in mind the purpose for which valuation is done and be careful about obtaining either a lower bound or an upper bound estimate.

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4

Valuation of Selected Environmental Assets

4.1 Introduction

As seen in the preceding chapter, valuation of natural resources is an essential element of IEEA. Value of a good depends on the purpose of valuation. In addition, value and market price are two different things. We all know that a gift or a memento received from a loved one is price less to us even though it may be worthless to others and if we try to sell it we get almost nothing for it. One may argue that these are two different markets. Yet the point is there is no unique price or value for the product. Similarly, without air we cannot live and yet air is free. These are common place observations and yet worth making again if only to clarify the assumptions, scope and limitations behind the kind of valuation of environmental resources that we carry out. A consistent set of assumptions and procedures are needed to avoid double counting and to obtain comparable estimates. The SNA does this rigorously by clearly defining what is included and what is not and by prescribing procedures for valuation. Thus, it includes only market or market-like transactions, excludes household work, values public services at costs and uses only market prices etc. These conventions impose limitations on the meaning and use of national income accounts which are well recognized. Developing a consistent system of valuation of natural environmental resources will require consistency of approach and clarity of purpose. We have already emphasized earlier that purposes can differ. The accountants' purpose may be different from the welfare analysts' purpose and consequently what we want to value in a particular situation will differ. The methodologies to use for valuation of degraded or depleted resources are particularly difficult to define for developing countries where data are poor and scanty. Also, markets for important resources like land are often thin and distorted and market prices do not reflect the true values of the resources.

In this chapter we describe some possible approaches to valuing resources of importance for developing countries. In particular, we describe how to value

degradation of agricultural land, depletion of exhaustible mineral resources and renewable regenerating resources such as forests and fisheries.

4.2 Valuation of Agricultural Land

In valuing agricultural land we want to value it as a productive asset. Land is used to grow crops to produce agricultural output. We want to value its use in such production. A particular piece of land may be precious to a person because it has belonged to his ancestors or is associated with family history. Such valuation is not included when we treat land as a productive agricultural asset.

Sometimes a piece of land may provide other services. It may be part of a beautiful landscape and when we change its use we may alter the beauty of the landscape. A piece of land may affect erosion or sedimentation on other land. Such aesthetic or environmental services provided by a piece of land are external to that piece and are not included when we value land as a productive asset for agricultural purposes.

If land were actively traded and land markets efficient, then the market would determine the loss in the value of soil due to degradation such as salination, water-logging or erosion. Unfortunately, agricultural land is hardly traded in many developing countries, and market price cannot provide information about the loss in the value of the soil. It is therefore, necessary to develop a method to value changes in soil quality. A farmer would like to know the trade-offs between intensive cultivation and resulting soil degradation that would reduce future yields. He may like to know the value of degradation of his land without going to market. Policy makers would like to know these trade-offs before promoting a new agricultural technology. It may also be in the society's interest to induce farmers to change land use and one should know how much the change is worth.

Apart from using market prices, a number of other approaches are possible to value changes in soil quality. The productivity approach estimates the present value of the loss in production now and in the future. The defensive/preventive expenditure approach used by IEEA estimates the cost that must be incurred now to avoid present loss in soil quality. For example, the cost of leveling and bunding to prevent soil erosion can be considered an upper bound on the cost of soil erosion (in terms of present value of future loss in production) in a situation of well functioning credit markets. If the costs of preventive measures were lower than the value of future loss, the farmer would undertake such measures. As Lutz, Pagiola and Reiche (1994) note, farmers tend to adopt conservation measures when it is in their interest to do so, unless some constraint is present. Yet another approach is the replacement cost approach which estimates the cost of restoring the soil to its original state. Norse and Saigal (1992) have used this approach for Zimbabwe to estimate the cost of soil erosion based on nutrient loss estimates. The avoidance cost and the replacement cost approaches are somewhat different. For instance, consider an automobile. Through regular oiling and preventive maintenance one can keep it in good running condition. Alternatively, when a particular part is worn out, it can be replaced with another one. In both cases the car may have the same service life and efficiency left. Yet the costs of the two approaches could be different. In general, one would follow the approach which costs less. When a farmer otherwise unconstrained chooses not to maintain or restore his soil, the costs of degradation must be smaller than the costs of maintenance or restoration.

A number of studies have used the productivity approach (e.g. Repetto and others, 1987 and Magrath and Arens, 1989). The loss in productivity is usually estimated from experimental data at a few locations. Data from such experiments are few and often concern only one or two characteristics such as soil loss or salinity. The impact on productivity of a whole range of soil characteristics is not generally estimated. Also, the representativeness of the experimental data to the varieties of agro-climate zones are not satisfactory. Thus, Magrath and Arens in their study of Java classify the land into 1100 possible combinations of 25 soil types, 11 erosivity classes and 4 land uses. However, because of scanty availability of experimental data for erosion-yield relationships, these were grouped into a far fewer number of classes. Similarly, Bishop and Allen (1989) used an erosion-yield relationship obtained from experimental data from Nigeria on maize and cowpea yields for Mali, uniformly for all crops and regions.

Our purpose here is to provide an approach that can be used for a large region to econometrically estimate the change in productivity due to changes in a whole set of combinations of physical and chemical properties of soil.

One also needs to value the loss in productivity in economic terms. It would not be strictly appropriate to assume that the same loss will recur year after

year as is done for simplicity by Repetto and others, (1987). Also, a farmer may adapt his cropping patterns or cultural practices to better suit the changed soil (quality/condition) and maximize his income. Farmers also react to public policy (Faeth and others, 1991 and Faeth, 1993) and optimum strategies of farmers may involve changes in soil quality (See Barrett 1992 and Ardilla and Innes, 1993). Thus, in valuing loss of productivity one should account for adaptation possibilities.

Our approach relies on the farmers' subjective assessment of the quality of their land and in an indirect sense accounts for such adaptation possibilities. The approach of estimating the value of changes in soil quality can be based on loss in productivity and the possibility of restoring soil quality through ameliorative measures as elaborated in Parikh K. (1989). The yield input relationship of a soil depends on climate, soil characteristics, inputs, genetic quality of seeds and cultivation practices. However, when one grows a crop, one not only produces that crop, but also some associated environmental joint products. Some soil may be lost due to cultivation through erosion by wind or water, the addition of fertilizers may change the chemical composition of the soil, water flowing off from the field may contain chemical residues and so on. These joint products may change the quality of the soil and hence its future productivity in terms of yield-input relationship.

Measuring quality by yield input relationship is cumbersome. One would like a simpler index. Operationally one can define an index in many ways. Hence, we make the simplifying assumption that the impact of inputs and soil quality on yields are separable. *Appendix 4A* provides a justification for this. Thus, yield is taken to be a product of a function *(f)* of inputs and another function *(g)* of soil quality parameters. The function *f* is called the input response function and the function *g* the soil quality multiplier function.

$$Yield = f\,(inputs)\; g\,(soil\ quality\ parameters) \qquad (4.1)$$

The first objective is to obtain an estimate of the soil quality multiplier in terms of easily observable and measurable parameters. The amount of potential yield or profits forgone due to a lower value of soil quality multiplier is a measure of the cost of depreciation of soil.

The soil quality multiplier is determined by a set of inherent physical and chemical properties of the soil. These are not under the direct control of the farmer, and can be adversely affected over time through excessive and improper use of irrigation and other inputs, and beneficially affected through amelioration measures such as use of organic fertilizer, leveling, provision of drainage etc. Some of these properties are affected by the actions of others such as neighbouring farmers, over which there may be no control.

One should note that farmers adapt their cropping pattern and inputs to changes in soil quality. The economic value of changes in soil quality can be considered as the difference in the present discounted values of profit streams with and without changes in soil quality.

We characterize a farmer's behavior as one which maximizes his discounted profits. Assume that in a given year t, a farmer can put n different inputs x^t_{ij} (i-th input to j-th crop) to produce m different outputs (crops) y^t_1, y^t_2, ... y^t_m from his land. Let the prices of the m outputs be p^t_1, ... p^t_m and costs of n inputs be c^t_1, ... c^t_n. Then his profit, V^t, will be

$$V^t = \sum_{j=1}^{m} p^t_j y^t_j \quad - \quad \sum_{i=1}^{n} c^t_i \sum x^t_{ij} \tag{4.2}$$

Profit = Price x outputs – Cost x inputs

The farmer decides how much output of each crop to produce and how much of each input to use. We assume that he does this in a way that maximizes the discounted present value of the stream of profits V^1, V^2, ... V^∞ discounted at a rate of ρ. This the farmer has to do within the constraints of the yield functions (4.1) which characterize the quality of his land and the technology of production that he possesses.

The quality of his land would vary over time. Along an optimal path, i.e., one which maximizes the present value of his profits, we assume that there is some stationarity if the production path is to be a sustainable one. By stationarity we mean that the value of the soil quality function g (soil quality parameters) would return to the same value every T period. T may be, 1 year or 5 years or 20 years. The implication is that the farmer follows a cropping cycle which periodically restores the quality of his land. While in principle, the optimal path need not show such stationarity, we will assume that since we are interested in sustainability, we will look for an optimal path that satisfies sustainability. The optimal value of V, call it V^*, is the value of land and it depends on the soil quality parameters. When soil quality changes V^* will change too. Thus, when the

vector of soil quality parameters, Q, changes from Q_0 to Q_1, the value of the land will change from $V^*(Q_0)$ to $V^*(Q_1)$.

This is shown in Figure 4.1 in which we have plotted annual profits against time for a piece of land. The path AEB depicts the optimal path where the initial soil quality is Q_0. It is a sustainable path along which every T years the soil quality is restored to its initial value Q_0. Path CD is a similar optimal path when the initial soil quality is Q_1. Along CD, the soil quality is restored to Q_1 every T_1 years. Of course, the present value of annual profits along optimal stationary paths is $V^*(Q_0)$. It may of course, be possible to follow a path like CEB starting with the initial soil quality Q_1. The present vlaue of profits along this path $V_1^*(Q_1)$ may be higher than along the stationary path $V^*(Q_1)$. If we assume that Q_0 is the optimal level of soil quality such that the present value of profits $V^*(Q_0)$ is greater than the present value of profits with any other level of soil quality changes from Q_0 to Q_1 is $V^*(Q_0)$ — $V_1^*(Q_1)$. However, for simplicity, we will take the change in the value of land to be $V^*(Q_0)$ — $V_1^*(Q_1)$. We note that this is an overestimate of change in soil quality.

We assume for simplicity that the percentage change in V^* is the same as the percentage change in the value of the soil quality function $g(Q)$. Now the

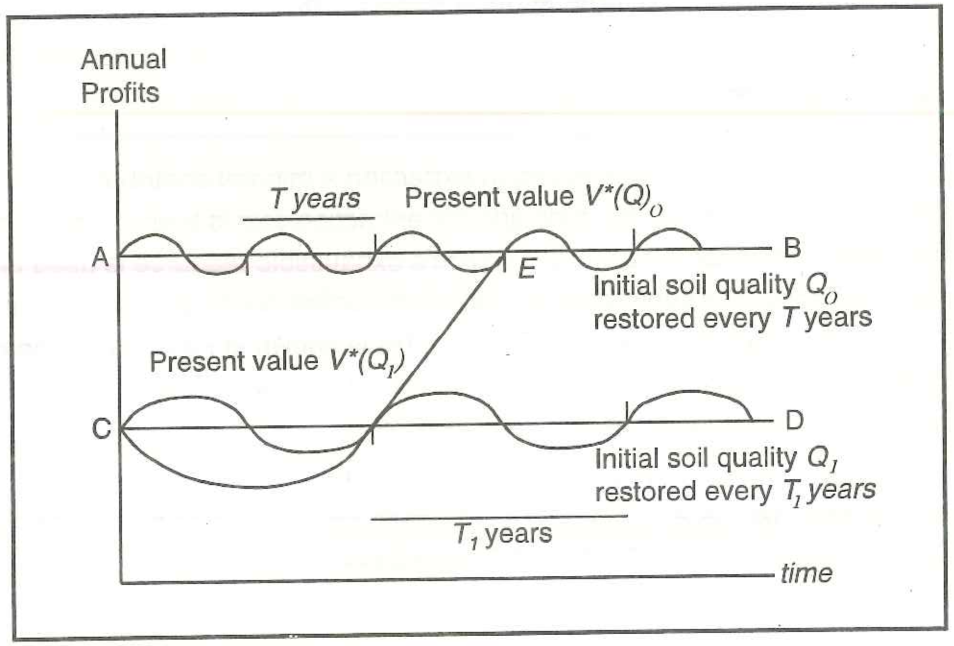


Figure 4.1: Soil quality and optimal sustainable profits

problem of valuation of agricultural land is reduced to valuation of the soil quality function $g(Q)$ and measurement of changes in soil quality parameters Q, i.e.,

$$\underbrace{\frac{V^*(Q_0) - V^*(Q_1)}{V^*(Q_0)}}_{\text{Percentage change in value of land}} = \underbrace{\frac{g(Q_0) - g(Q_1)}{g(Q_0)}}_{\text{Percentage change in value of soil quality function}} \tag{4.3}$$

Equation (4.3) forms the basis of estimation of change in value of agricultural land as a productive asset. One should note that in a competitive set up

$$\text{Cost of land degradation} = \text{Min}\left[\begin{pmatrix}\text{Avoidance}\\\text{cost}\end{pmatrix}, \begin{pmatrix}\text{Restoration}\\\text{cost}\end{pmatrix}, \begin{pmatrix}\text{Loss in}\\\text{productive}\\\text{asset value}\end{pmatrix}\right] \tag{4.4}$$

This approach has been applied to India and using cross section data, soil quality functions have been estimated for different states by Parikh and Ghosh (1995). This can be used to prepare a satellite account for agricultural land as shown in Boxes 4.1 and 4.2.

4.3 Valuation of Exhaustible Mineral Resources

4.3.1 The problem

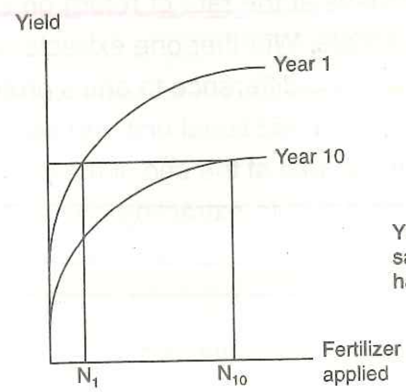
In the standard SNA, value added in extracting a mineral contributes to GDP. The difference between the price and the extraction cost is treated as profits of the owner. However, a part of the nation's exhaustible resource is used up its value and should be subtracted as cost of production due to depletion of natural resource to obtain the true value added. This is shown in Figure 4.2. The cost of depletion of reserve is also called user cost. We want to correct the SNA practice and the question is how best to do it.

Since in valuation we attempt to estimate what a competitive market would do if all externalities are internalized, it would be useful to review some basic ideas in the economics of exhaustible resources.

Box 4.1: Agricultural Production and Soil Productivity

Agricultural production can bring about changes in the chemical [acidity, salinity, changes in organic content, changes in nutrient availability etc.] and/or physical [decrease in soil depth due to erosion, water logging etc.] properties of soil. Use of land for agriculture in sloping terrain will increase the rate of soil erosion compared to forested land. Similarly, crops sown can affect the rate of erosion. Crops with thick vegetative growth will cause lower erosion. Cultivation practices alter the permeability and looseness of soil which controls the erosion rate. Cultivation practices which slow down the run-off from land reduce the erosion rate. Similarly, repeated cropping of land without recycling of organic matter will lead to reduction of soil organic content. Intensity of cultivation too affects the soil quality. Increased intensity reduces the time gap for recuperation of soils and also increases extraction of soil nutrients. Changes in soil quality in turn will affect the productivity of the land.

The sustainability of agriculture requires the preservation of soil productivity. Sustaining soil productivity can be defined as constant or increased output at constant or decreased input level. For example, as shown in the figure production can be maintained in soils in which nutrient depletion has taken place by increased use of fertilizers. Thus, the production has not decreased in this case. However, the cost of production has increased as the productivity has decreased.



Yield has remained the same but productivity has gone down.

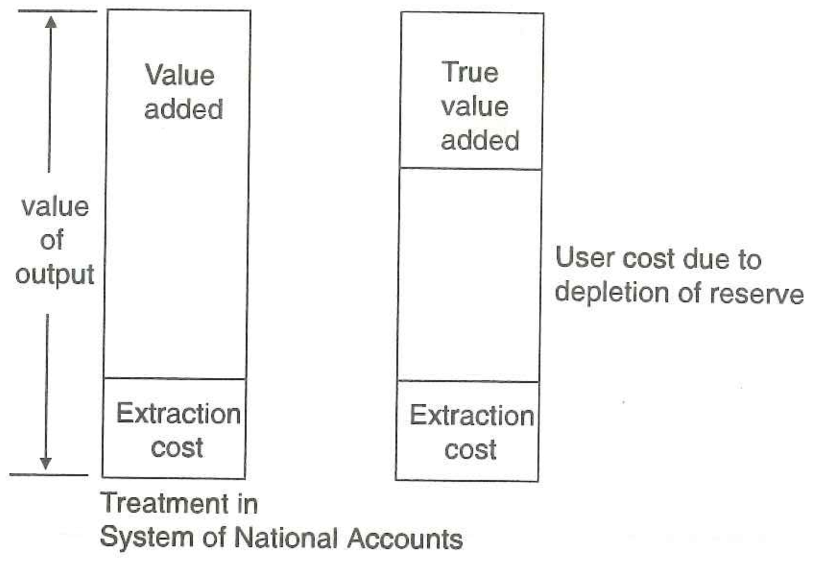


Figure 4.2: User cost of depletion of reserve and true value added.

4.3.2. Optimal extraction rate, true income and depreciation

A question that has occupied economists is what the optimal extraction rate is. The optimum will depend on the objective function; a special case would be to derive a *sustainable* extraction path. A number of answers to these questions have been offered.

In a competitive set up, with no extraction cost, the price of an exhaustible resource which is scarce increases at the rate of return on capital (or interest rate). The logic behind this is simple. Whether one extracts one additional unit today or a year later should make no difference to one's profit or wealth. If the price is P_o today, one can extract an additional unit and sell it for P_o, investing the proceeds to obtain a return r so that at the end of the year, one would have $P_o(1 + r)$. This profit should be equal to extracting one unit a year later and selling it at a price P_1. Thus,

$$P_1 = P_o(1 + r) \quad (4.5)$$

By extending this argument to t years, we get

Box 4.2: Valuing Agricultural Land for a State in India

The approach described here is illustrated with an application to the state of Haryana in India. Information on soil quality parameters was collected by a survey which covered 21,500 farm households across India for two consecutive years - 1975-76 and 1976-77. The survey collected information on the following six soil characteristics parameters for each farm. Together, they make 20 different parameters :

- Soil type (sand, loam, light clay, *heavy clay*).
- Soil colour (red, black, gray and *yellow*).
- Soil depth (1 foot, *1-3 feet*, 3 feet).
- Soil salinity (nil, *moderate*, high).
- Surface drainage (good, *moderate*, poor)
- Rate of percolation (high, *moderate*, low).

Along with this, the survey also asked the respondents to rank their land quality. This was used as the dependent variable. The following functional form was estimated for each state using this survey data (See Parikh and Ghosh (1991)).

$$\text{Soil Quality Index} = \alpha + \Sigma \beta_i Q_i$$

where Q_i is the dummy for the different soil quality parameters i.e., if the particular parameter describes the soil, the Q_i will be 1.0 otherwise 0. β_i's are set to zero for the six parameter descriptions shown in *s*. The intercept term α therefore gives the soil quality of a farm with these parameters namely – heavy clay, yellow in colour, with 1-3 ft. soil depth, moderate salinity, moderate permeability and moderate rate of percolation. The β_i's for other parameters represent the chnge in soil quality from the value of soil quality with the six italicised parameters. Parikh and Ghosh show that the state level average soil quality is given by

$$g^{state} = \alpha + \Sigma \beta_i A_i$$

where A_i is the proportion of area under each type of soil quality parameter.

The following exercise demonstrates the use of the above function in estimating changes in land value. For this exercise, the Indian State of Haryana was chosen as an example

The estimated coefficients β_i's and the proportion of area under each attribute in the state of Haryana are given below. The table also shows how the area under different soil quality classes change from year t to year t + 1 in a hypothetical situation. We have assumed that 10 per cent additional land becomes highly saline and 10 per cent additional land gets eroded. The table below thus constitutes a physical account of soil quality change.

(contd...)

Box 4.2 (Contd.)

Physical Accounts of Agricultural Land		**Percentage of cultivable area under different categories**	
Physcial and chemical property	Coefficient β_i	**Year$_t$**	**Year$_{t+1}$**
Intercept	2.344		
Soil Texture			
Sand	-0.074	17.9	17.9
Loam	-0.017	68.3	68.3
Light clay	-0.007	13.5	13.5
Heavy clay	0	0.3	0.3
Soil Colour			
Red	0.006	24.7	24.7
Black	-0.000317	1.9	1.9
Gray	-0.085	69.7	69.7
Yellow	0	3.7	3.7
Soil Depth			
1 foot	-0.069	29.8	**39.8**
1-3 feet	0	27.7	27.7
3 feet	0.009	42.5	**32.5**
Salinity			
Nil	0.032	67.9	**57.9**
Medium	0	31.5	31.5
High	-0.079	0.6	**10.6**
Drainage			
Good	0.132	79.1	79.1
Medium	0	19.5	19.5
Poor	0.65	4.1	4.1
Percolation			
Fast	0.364	40.1	40.1
Medium	0	57.0	57.0
Slow	0.268	2.4	2.4
g(Q)		12.505	12.266
Percentage change in *g(Q)*			-1.91

The economic value accounts of agricultural land in Haryana in a hypothetical situation in which an additional 10 per cent of the state's land is eroded and an additional 10 per cent becomes highly saline is as shown below.

Net cultivable land	=	3792000 hectares
Value added in agriculture in 1995	=	Rs. 59.722 billion
Net cropped area (NCA)	=	3575000 hectares
Net productivity (value added) per unit NCA	=	Rs. 16705
Net present value (NPV) of a unit hectare in 1995 (Using 10% discount rate)	=	Rs. 183760
Initial value of total land	=	183760 x 3792000 = Rs. 697 billion.
Depreciation due to change in productivity	=	697 x 1.91/100 = Rs. 13 billion.

Final value of total land = 69.7 × (1- 0.0191) = Rs. 684 billion.

$$P_t = P_o (1 + r)^t \quad (4.6)$$

This gives the classical Hotelling rule for exploitation of exhaustible resources. A monopolist can vary the amount of resource extracted in such a way that the above relationship is satisfied. That would maximize the worth of his resource and would be the optimum exploitation strategy.

Suppose, however, that after *T* years a substitute is expected to limit the price P_T to $\overline{P}$. Then the same rule still applies and

$$P_T = \overline{P} = P_o (1 + r)^T \quad (4.7)$$

so that $$P_o = \overline{P} / (1 + r)^T \quad (4.8)$$

One can easily adapt the rule to take care of other situations such as non-zero costs of extraction, shifting demand, and so on. (See for example, Pearce and Turner 1993).

What is a sustainable rate of extraction? One answer was given by Solow (1986); where in his neo-classical world, the exhaustible resource is always needed but can be substituted by other inputs, albeit at an increasing rate as the resource input becomes smaller and smaller. It is shown that if you extract the resource and use it to sufficiently augment the availability of its substitutes then you can for-ever sustain the production of the good that needs this exhaustible resource as an input. Of course, you would be extracting a smaller and smaller quantity of the resource and will never exhaust it fully.

This idea of a permanent income has been used by El Serafy (1993) to calculate the true income from the use of exhaustible resources. What part of the extraction income is available for current consumption and what part is needed for accumulation to compensate for depletion of the resource? El Serafy suggests that we can equate the present value of the resource to the present value of an annual income available forever. That annual income is the true income as it is available forever and any income in excess of that is really depreciation of your capital stock.

4.3.3. Valuation approaches

One approach to valuation of depletion of an exhaustible resource starts from the perspective of the resource owner. He can sell his entire stock at a time t and get an amount V_t. He can put this in the bank at a rate of interest *r* and earn an income of rV_t forever. This is sustainable income as it preserves the value of the capital stock. Suppose instead, the owner works the resource and sells an amount Q_t at a price P_t to earn a net profit R_t. In addition, at the end of the year his asset value would change to V_{t+1}. In equilibrium, he should be indifferent to the value between the two. Thus, in either case, at the end of the period t would have :

$$rV_t + V_t = R_t + V_{t+1} \quad (4.9)$$

i.e. $$rV_t = R_t + (V_{t+1} - V_t) \quad (4.10)$$

i.e $$(V_t - V_{t+1}) = R_t - rV_t \quad (4.11)$$

Depreciation = Net receipts - Sustainable income.

This is the basic relationship used in various methods suggested for correcting GDP for depletion of an exhaustible resource. Note here that V_t is valued at the beginning of period t and R_t are the net receipts, net of conventional cost of production, at the end of the period t.

The conventional SNA would include R_t as income in GDP. We need to subtract from this the depreciation of the asset namely $(V_t - V_{t+1}) = R_t - rV_t$.

How do we estimate V_t? We can know V_t directly if the asset has been recently traded so that the market price is available. If not we have to use a theoretical approach. The theoretically correct way is to define V_t as the present value of the asset under an optimal (competitive) exploitation plan. Thus,

$$V_t = R_t \frac{1}{(1+r)} + R_{t+1} \frac{1}{(1+r)^2} + \ldots + R_{t+i} \frac{1}{(1+r)^{i+1}} + \ldots + R_{t+n} \frac{1}{(1+r)^{n+1}} \quad (4.12)$$

Note here that to know V_t we have to know the stream of R_{t+i} and the interest rate (opportunity cost of capital) r.

Since this is difficult, certain simplifying approaches have been proposed. Thus, El Serafy assumes that over the remaining lifetime R_{t+i} would remain constant, i.e., $R_{t+i} = R$ for all i. With this assumption and a given r, one can determine R (and the number of years over which the mine will be exhausted), which will maximize V_t. On the other hand, Repetto and others (1989) assume that price will adjust optimally over the lifetime so that $P_{t+1} = P_t(1+r)$. This gives

$$V_t = P_t (\Sigma Q_{t+i})$$

i.e. (Present discounted value of asset in period t) = (Profit rate in period t) x (Sum of all quantities extracted over the lifetime)

These two assumptions give different results. Which is preferable? Since both are based on assumptions, it is difficult to prefer one over the other. However, the authors have a marginal preference for Repetto's assumption as his is consistent with optimal behaviour in a competitive environment.

Even when one has identified the depreciation as $(V_t - V_{t+1})$, there is still a question: what portion of $(V_t - V_{t+1})$ is cost of production (user cost) and what is revaluation of the asset/stock?

The problem looks simple if we consider the resource as an inventory. Thus,

Value of inventory at the end of period	=	Value of inventory at the beginning of period	–	Cost of using up part of inventory	+	revaluation of the remaining inventory.

Whatever is sold during the year is really taken away from the inventory and represents user cost. El Serafy (1993) has argued persuasively that user cost for an exhaustible resource does not constitute value added and the conventional estimate of GDP should be corrected by subtracting the user cost. Thus the cost of production (user cost) is taken to be net receipt R_t. Let us elaborate the inventory approach. Suppose one has a total inventory of stock Q which has an initial value $Q.P_t = V_t$. Here P_t is the net price, net of conventional costs of extraction. One can decide each year how much one can sell. If in year t, one sells Q_t at price P_t, one's income is $R_t = P_t Q_t$ and at the end of the year one would be left with stock $Q - Q_t$. Since one has to bear the carrying charges (interest forgone) on this amount, its value at the end of the year would be $V_{t+1} = (Q - Q_t)\, P_t\, (1+r)$. The difference between $(V_t - V_{t+1})$ and R_t is thus, revaluation of the asset.

4.3.4 Valuation of new finds

In valuing such resources often only proven reserves are considered. There is a problem on how to treat new finds. If these are added to reserves one gets the uncomfortable result that one has used up part of one's exhaustible resource and yet one is left with more of it. There are two ways to deal with this. The first one is as described in Parikh and others, (1993) and is as given below.

The different categories of resources shown in Figure 4.2 range from economic measured to submarginal speculative. The differences in value of different categories can be based on the expected differences in the costs of finally producing it. Thus, for example, to shift a resource from the category inferred to the category demonstrated requires geological exploration, then the difference in the values of these two categories should be the expected cost of such exploration.

To formalize these ideas, let

Q_{ij} = The reserves of the ith economic category (i = economic, paramarginal and marginal) of jth reliability category (j = measured, indicated, inferred, hypothetical and speculative).

C_i = Cost of producing one unit of the ith type of reserve (it is assumed that before production, the reserve must be shifted to the measured category)

E_{ij} =Expected expenditure on exploration required to change the probability of one unit of reserve of the category ij to category i, j-1.

The value of the resource is the price of the particular resource *P* minus the cost of producing it. Thus, V_{ij}, the value of reserves Q_{ij} is given by :

$$V_{ij} = (P - C_i \sum_{k=2}^{j} E_{ik}) Q_{ij}$$

And the value of the total reserves is given by summing up V_{ij} for all elements in the resource matrix for which V_{ij} is positive and is given by

$$V = \Sigma\Sigma V_{ij} \quad i, j \mid V_{ij} \geq 0$$

It may be noted that when the price at which a resource can be sold increases, previously uneconomical reserves become economical. This way of valuing the stock of exhaustible resources accounts for the value of exploration and the knowledge resulting from it. The time and gestation lags involved in exploration and production can easily be taken care of by defining the C_i's and the E_{ij}'s as present values including interest costs.

In an alternative method, we should consider the depreciation of existing reserves as a natural resource depreciation and treat new finds differently. New finds are really the product of exploration activities. Suppose exploration was

carried out by a firm and as soon as it proved a reserve it would sell it off to other developers. In such a case the output of the exploration enterprise would be the sale price of its finds and value added will be calculated on that basis. In a sense it is no different than a firm that produces a durable capital good. Thus

- GDP should include the value of the new finds
- Depletion should be based on reserves known at the beginning of the period.

Total resources

		Identified		Undiscovered		
		Demonstrated				
		Measured	Indicated	Inferred	Hypothetical	Speculative
Economic		Q_{11}	Q_{12}	Q_{13}	Q_{14}	Q_{15}
		Reserves				
Sub-economic	Para-marginal	Q_{21}	Q_{22}	Q_{23}	Q_{24}	Q_{25}
	Sub-marginal	Q_{31}	Q_{32}	Q_{33}	Q_{34}	Q_{35}

Figure 4.3 A categorization of stock resources

Terms : Identified resources: specific bodies of mineral bearing material whose location, quality and quantity are known from geological evidence

Measured resources: material for which quantity and quality estimates are within a margin of error of less than 20 per cent, from geologically well known sample sites.

Indicated resources: material for which quantity and quality have been estimated partly from sample analyses and partly from reasonable geological projections.

Inferred resources: material in unexplored extensions of demonstrated resources based on geological projections.

Undiscovered resources: unspecified bodies of mineral bearing material surmised to exist on the basis of broad geological knowledge and theory.

Hypothetical resources: undiscovered materials reasonably expected to exist in a known mining district under known geological conditions.

Speculative resources: undiscovered materials that may occur either in known types of deposits in favourable geological settings where no discoveries have been made, or in yet unknown types of deposits that remain to be recognized.

Source: U.S. Geological Survey (1976).

However, you would still be required to value different categories of proved resources, for which the method described above can be used.

Note that the table in Figure 4.3 constitutes a physical account when tables at the beginning and end of the year are compared.

4.4 Valuation of Forests

To outline approaches for valuation of forests we should first examine the role that forests play in providing economic and ecological services. The following subsection taken largely from Parikh, Parikh, Sharma and Painuly (1993) describes the role of forests.

4.4.1 Role of forests

Forests are one of the most important components of the natural resource and environmental system. Forests, however, contribute to the local ecosystem as well, and play a multidimensional role. The provide livelihood to the poor who depend on them for food, fodder, fuel and many minor forest products. While the forests were cleared for agricultural and industrial purposes in North America and Europe in the eighteenth and nineteenth centuries, the focus of the current debate is deforestation in the tropics, particularly in developing countries. Tropical forests contain more than half of the world's plant and animal species and are the major source of available biodiversity. The global concern about clearing these forests, therefore, relates to the twin problems of destruction of the carbon sinks affecting the global climate and extinction of species affecting biodiversity. The rural poor in the third world have been blamed for deforestation in the past, but there has been a gradual realization that it is mainly the commercial interests of the governments or the urban areas that have driven the wheels of deforestation; for example, the deforestation of the Brazilian Amazon (Repetto, 1988). In India too, forest departments have blamed the rural people and their animals for destruction of forests to the extent that one of the committees constituted by the Union Ministry of Agriculture even suggested curtailing the rights of the rural people to the forests (CSE, 1985).

Such an approach fails to consider the dynamics of rural survival and their relationship with the forests in terms of land for crops, fuelwood for cooking and

fodder for the animals. It also fails to estimate the role of commercial interests in degradation and deforestation. Industries like timber, paper, packing, tobacco etc. are intensive users of wood and forest produce. Further, economic advancement and urbanization does not reduce the reliance on forest products. As the country develops, wood remains a basic raw material for construction, furniture, rail sleepers, power poles, rayon, plastics, etc. (Eckholm, 1991). The net result of ever increasing urban and industrial requirements for wood and rural dependence on forest produce has led to an erosion of forest wealth in many countries. The diminishing availability of biomass has affected the quality of life of rural people in India (Gadgil, 1991). It is the poor people whose survival is related to diversity of plant and animal matter.

Resources for subsistence, shelter and employment as well as resources for the development of other sectors are provided by forests. They play a positive role in the agroforestry farming system practiced widely in developing countries. An appropriate assessment of forest functions is required before a valuation of forests as a resource can be considered. It is, therefore, necessary to understand the functions that they perform for natural and social systems. These functions are given in Table 4.1.

Tropical moist forests are of immense ecological value owing to biological diversity and the high rate of vegetation. They contain huge numbers of yet unknown species of plants and animals and their destruction is associated with extinction of the species. The species discovered so far have been sources of medicines, crops and other consumption items. The tropical forests are the world's largest genetic reservoirs, estimated to contain more than 50 per cent of the number of species on the planet. The significance of forests in regulating the regional and local climate is well known. They are important participants in the water and energy chain of the ecosphere.

The productive role of forests can be divided into two broad categories as shown in Table 4.2.

4.4.2 Towards an accounting system for forests

The national accounts have so far considered mainly commercial wood in the existing framework, at the cost/price at which it is transacted in the market. In addition to that, a small amount of fuelwood (less than 10 per cent of actual

Table 4.1 : Functions of forests

For the Natural System	For the Social System
Protective	
- soil protection by absorption and deflection, radiation, precipitation and wind	- sheltering agricultural crops against drought, wind, cold, radiation
- conservation of humidity and carbon dioxide by decreasing wind velocity	- conserving soil and water
- sheltering and providing required conditions for plant and animal species	- shielding man against nuisances (noise, sights, smells, fumes)
Regulative	
- absorption, storage and release of CO_2, O_2 and mineral elements	- improvement of atmospheric conditions in residential and recreational areas.
- absorption of aerosols and sound	- improvement of temperature regimes in residential areas (roadside trees, parks).
- absorption, storage and release of water	- improvement of the biotype value and amenity of landscapes
- absorption and transformation of radiant and thermal energy	
Productive	
- efficient storage of energy in utilizable form in phyto- and zoomass	- supply of a wide array of raw materials to meet man's growing demands
- self-regulating and regenerative processes of wood, bark, fruit and leaf production	- source of employment
- production of a wide array of chemical compounds, such as resins, alkaloids, essential oils, latex, pharmaceuticals, etc.,	-
In the case of tropical forests the first two functions - protective and regulative - are extremely important and not very well-known while the third - productive - is largely underestimated and underused.	

Source: ICHI (1989)

consumption in a developing country like India) also enters into the accounts. There is no provision to account for the depreciation and degradation of the forest capital that has been occurring over a period of time due to over exploitation. Such degradation (and depreciation) results in a loss of some of the valuable functions (listed earlier) performed by the forests. The loss of functions leads to monetary and other types of damage to the ecosystem necessitating monetary expenditure to repair the damage. Such costs are not estimated and reflected in the national accounts. Even an appropriate framework to value these functions does not exist. As a result the loss due to degradation is difficult to estimate. Attempts have been made to include the

Table 4.2 : The productive role of forests

Category	Products	Affected Sectors/Users
Indigineous consumption	Fuelwood and charcoal	Cooking, heating and household uses
	Agricultural uses	Shifting cultivation, forest grazing, nitrogen fixation, fruits and nuts.
	Building poles	Housing, buildings, construction, fencing, furniture
Industrial uses	Pit sawing and sawmilling	Joinery, furniture, construction, farm buildings
	Weaving materials	Ropes and string baskets, furniture, funishings
	Sericulture, apiculture, ericulture	Silk, honey, wax. lac
	Special woods and ashes	Carving, incense, chemicals, glass making
	Gums, resins and oils	Naval stores, tannin, turpentine, distillates, resin, essential oils
	Charcoal	Reduction agent for steel making, chemicals
	Poles	Transmission poles, pitprops
	Sawlogs	Lumber, joinery, furniture, packing, shipbuilding, mining, construction, sleepers
	Veneer logs	Plywood, veneer furniture, containers, construction
	Pulpwood	Newsprint, paperboard, printing and writing paper, containers, packaging, dissolving pulp, distillates, textiles and clothing
	Residues	Particle board, fiberboard, wastepaper

Source: World Bank Policy Paper on Forestry (Washington, D.C.: World Bank, 1978).

forests as a resource in the SNA. However, only physical units have been considered in the SNA. The IEEA proposes to assign monetary values to these units as a satellite account of SNA. The WRI (Repetto, and others, 1989) has also attempted to include forest accounts in a few country case studies and demonstrated that as a result of inclusion of costs due to degradation and destruction of forests and other natural resources, the economic growth rate works out to be lower than that claimed by these countries in their national accounts. Repetto, and others, however, consider only the commercial value of timber to calculate the depreciation of forest stock.

The various functions fulfilled and benefits provided by forests described in Tables 4.1 and 4.2 can be grouped differently for the purposes of valuation. Pearce and others, (1991) provides a scheme for calculating total economic value (TEV) of forests. This consists of direct value, use values further divided into indirect value and option value, and non-use value. This classification is based on the types of methods needed for valuation.

It is difficult to value the ecological functions of forests because of gaps in knowledge and data (Myers, 1988). We need to understand the vegetation / atmospheric interactions. A reduction in vegetation leads to declining rainfall and this in turn may affect agriculture, hydropower energy and public health. A knowledge of these interactions and an estimate of consequences is required for assessment of costs related to depreciation of the vegetation cover. Both these areas need research. Also, in ecological systems there are discontinuities. These are the inflection points at which conditions suddenly and rapidly deteriorate. For example, acid rain when it exceeds a certain limits can transform a growing healthy forest into a dying one. Thus, forests may be able to absorb stresses to a certain level without showing it, but a stage of sudden disruption may occur. That may involve high costs in removing the stresses and yet the system may not be able to attain the old equilibria. These points and corresponding level of human activities, costs to restore the system etc. need to be researched.

A resource accounting system for forests has to be confined to its productive functions till the above gaps in information and knowledge are filled. The first step is to set up forests as a satellite account to national accounts systems in physical units, based on the available estimates. The stocks and

Table 4.3 Economic valuation of forests

Direct Value	Use Values		Non-Use Values
	Indirect value	Option value	
Sustainable timber products	Nutrient cycling	Future uses	Existence value
		Direct and indirect values	Biodiversity
Non-timber products	Watershed protection		Culture
Recreation	Air pollution reduction		Heritage
Medicine	Micro-climatic functions		
Plant genetics	Carbon store		
Education			
Human habitat			
Life support (tribal etc.)			

Source: Pearce and others, (1991)

flows for different types of forests/plant species can be estimated. These can be evaluated using the currently available valuation methods, which would give the accounts in monetary terms.

The total economic value (TEV) approach can also be utilized to assess cost of deforestation as well as to evaluate different options for forest use. For example, it can be used to evaluate development options for the forest. Costs and benefits of different forest land-use options can also be worked out using TEV. There may be a lot of uncertainty about numbers used in the evaluations and these may also be subject to revisions. It is, therefore, suggested that the forest natural resource block should be in physical quantities, and if the valuation is also done, the corresponding monetary block should have all the information related to conversion from physical to monetary units. The direct values are the resource and services provided by the forest whereas the indirect values are the environmental functions of the forests. Option value is the willingness to pay if a resource has to be conserved for future use. Existence value of a forest reflects the intrinsic value (or the value placed by the people on the forest itself) and it is not related to any use.

4.4.3 Valuation of forests as a productive asset: direct use value

The income one would derive from a forest would depend upon the strategy of management. The price that a competitive market for forests would fetch would correspond to the present value of the income stream generated under an optimal management plan. This is what one should try to estimate. Suppose the optimum strategy for a given forest is to let it grow for T periods and then harvest it. Let

$m_1,\dots m_t,\dots, m_T$	be the income derived from sale of non-timber products. If there are no markets for those, a social value may be put on them.
$v_1,\dots, v_t,\dots, v_T$	be the volume of saleable timber if the forest is clear felled at the end of period t.
$p_1,\dots, p_t,\dots, p_T$	be the corresponding price of timber.
$l_1\dots, l_t\dots, l_T$	be the price of clear felled land.

Then the present value V_t of the stream of income when the felling is done in period t, and the discount rate is r is as follows :

$$V_t = \sum (p_i v_i + m_i) / (1+r)^i + l_t / (1+r)^t \tag{4.14}$$

We have assumed that clear felling at end of period T is optimum, i.e.

$$V_T > V_t \qquad \text{for } t \neq T$$

If land markets do not function well we do not know the value of l_t. This can be derived in the same spirit. Let the optimum strategy on clear land be to plant a forest and harvest it after τ years. We will assume that m_i are net receipts excluding the cost of replanting, management etc. Then

$$l_\tau = V_\tau = \sum_{j=1}^{\alpha} \left\{ \sum_{i=1}^{\tau} (p_i v_i + m_i) / (1+r)i \right\} / (1+r)^{(j-1)\tau} \tag{4.15}$$

This expression gives the present value of repeatedly planting the land and clear felling it after every τ years. This value of l_τ can be substituted in the previous equation, and each type of forest can be so valued.

While the information on timber output from forests of different age may be available from foresters, how do we get the prices for the future? Just as there is an optimal strategy to exploit an exhaustible resource and there is a relationship for a price of the resource across time, one can also establish such relationships for living resources like forests and fisheries. Ward and Hamilton (1996) show that the efficient path that maximizes present value of profits requires the unit profit rate (i.e., price minus marginal harvest cost) n_t to satisfy.

$$\frac{n_{t+1} - n_t}{n_t} = r - g(S_t) / S_t \tag{4.16}$$

where r is the discount rate and $g(S_t)$ is the natural growth which is a function of the timber stock S_t. In a steady state the profit rate remains the same so that $n_{t+1} = n_t$, i.e., the forest is allowed to grow to such a state that the constant harvest rate equals the natural growth rate which equals the discount rate.

The optimum rule is easy to derive from simple arguments, similar to the one used before for exhaustible resources. An owner has the possibility of selling his entire stock of standing timber at a time t. The profit on this is the value of his stock. Thus,

$$V_t = n_t S_t$$

The owner can sell this, put the money in a bank and earn interest rV_t at the end of the year, when he will have $V_t(1+r)$ which should equal the value of his stock V_{t+1} at the beginning of period t+1. But the stock S_t is now given by $g(S_t)$. So that

$$\begin{aligned} V_{t+1} &= n_{t+1} (S_t + g(S_t)) = V_t(1+r) = n_t S_t(1+r) \\ (n_{t+1} - n_t) S_t &= n_t r S_t - n_{t+1} g(S_t) \\ \frac{n_{t+1} - n_t}{n_t} &= r - \frac{n_{t+1}}{n_t} g(S_t) / S_t \end{aligned} \tag{4.17}$$

If we write $n_{t+1} = n_t + \Delta n_t$ and take $\Delta n_t . g(S_t)/S_t$ to be small enough to be negligible, Equation (4.17) reduces to (4.16).

This relationship can be used to obtain an equilibrium n_t and corresponding p_t and assuming it to be constant or evolving according to some scenario of changing demand, one can estimate the value of a forest using equations (4.14) and (4.15) of this section.

Here we have considered that the forest produces only one type of timber product. The above framework can easily be used if a variety of timber products are produced. All we have to do is to consider that each v_i is a vector of different types of timber output in year i and p_i is the vector of the corresponding prices.

The valuation of non-timber products m_i often gathered free of cost by the poor living nearby, or by tribals living in the forests, poses some problems that need to be underlined.

Some of these products are traded and have a market price. These are easy to value. The difficulty arises in valuing the others. Sometimes people have valued such products in terms of person hours spent collecting them. Here, however, one has to be careful in using the proper opportunity cost of labour. If the poor villager has no other option for paying work he may spend many hours gathering something of use from the forest. If the product is traded, its price can provide an idea of the implicit return on labor that the person has earned. This may be very small.

Of course, one should also recognize that such poor persons who have few other opportunities for earning an income, have a very high marginal utility of income. Thus even the small addition to income that the gathered forest products amount to may have a very high survival value. From a social

We can rewrite the above equation as

$$C^g = \alpha^t (w^g E^g)^\beta (E)^\gamma \qquad (4.23)$$

where $\alpha^t = \alpha (F^t)^\delta$

We can estimate α^t, β and γ from a cross-section time-series regression. γ captures the effect of overcrowding. Knowing γ we can estimate the adjusted loss in productivity.

$$\Delta V_t = \Delta V^t \left(\frac{E^{t-1}}{E^t}\right)^\gamma \qquad (4.24)$$

We should recognise that this is an approximation. But given the lack of data this is perhaps the best one can do. If one had all the data on fish population and growth dynamics one could formulate the problem as follows :

The value of fish stock F^t at the beginning of the period t is the maximum profit in the present discounted value of a stream of catch C^t which satisfies a sustainability constraint. In the spirit of the Bruntland Commission report, we impose the sustainability constraint by requiring that at the end of one generation say after 20 years, the fish stock should be better than what it was at the beginning. Formally, V^1, value of fishery stock F^1, is given by

$$V^1 = \text{Maximize} \sum_{t=1}^{20} P^t C^t/(1+r)^t$$

Subject to

$F^{21} \geq F^1$ sustainability constraint.

and $F^{t+1} = f(F^t, C^t)$ stock accumulation/depletion.

Thus $\Delta V^t = V^{t+1} - V^t$ will be the depreciation when fish stock changes from F^t to F^{t+1}.

Equation (4.23) can be estimated by the data that is collected in some countries.

4.6 Concluding Observations

The approaches to valuation of resources such as soils, minerals, forests and fisheries described here are motivated by the scarcity of data which is common

in this area, particularly in developing countries. They rely on data likely to be available or which can be collected through sample surveys.

We hope we have shown that a beginning in valuation of natural resources is possible and that one should be able to get a quantitative understanding of consequences of economic activities on environmental and natural resources of a country. Preparation of such accounts, even for a limited set of resources, would lead to a more informed awareness among people and policy makers and, in turn, to better policies. It would also stimulate collection of better and more relevant data.

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Appendix 4A: A Separable Representation of Yield Function for Soils

To justify the assumption of separability in Equation (4.18), consider the conventional production function for a piece of land whereby yield Y (output per unit land) is related to inputs X1, (i = fertilizer, water, capital etc.)

$$\text{Thus, } Y = A \cdot \prod_i (X_i)^{a_i} \qquad (A.1)$$

The impactof soil quality is embodied in the constant A and also in the parameters a_i's. To use this over lands of different classes, we begin with some agronomic insights. Some agronomists have argued that the function of soil is merely to serve as a medium to transport nutrients to the plant. Thus only input uptake (i.e., how much input reaches the plant) depends on soil quality but the yield to input uptake relationship is independent of soil quality (see de Witt and others, (1965) Linnemann and others, (1979)). We can thus rewrite the function as follows - where the parameters α_i's are independent of soils.

$$Y = A \prod_i (X_i^{uptake})^{\alpha_i} \qquad (A.2)$$

The uptake of an input depends on how much input is applied on the soil. We characterize the soil by its various soil quality indicators Qj (j = type of soil, permeability, depth, salinity etc.). Then,

$$X_i^{uptake} = (\prod_j e^{r_{ij}Q_j})\, X_i^{applied} \qquad (A.3)$$

Where Qj are the various soil quality indicators and r_{ij}'s are parameters. Similarly, a can also be written as

$$A = A_o \prod_j e^{r_{oj}Q_j} \qquad (A.4)$$

Substituting (A.3) and (A.4) into (A.2), we get

$$Y = A_o \prod_j e^{r_{oj}Q_j} \prod_i \left[\left(\prod_j e^{r_{ij}Q_j}\right) X_i^{applied}\right]^{\alpha_i} \qquad (A.5)$$

Simplifying (A.5) we get

$$Y = A_o \left[\prod_j e^{[r_{oj} + \sum_i r_{ij}\alpha_i]Q_j}\right] \left[\prod_i X_i^{applied}\right]^{\alpha_i} \qquad (A.6)$$

If we write

$$B_j = r_{oj} + \sum_i r_{ij}\alpha_i \qquad (A.7)$$

the n we can write (A.6) as a product of two functions, the soil quality multiplier, g, as

$$g\,(\textit{soil quality parameters}) = A_o \prod_i e^{B_j Q_j} \qquad (A.8)$$

and the input response function, *f*, as

$$f\,(\textit{inputs}) = \prod_i (X_i^{applied})^{\alpha_i} \qquad (A.9)$$

which gives

y = g (soil quality parameters) f (inputs)

Appendix 4B: Value of Soil and Soil Quality Function

The soil quality function g is determined by a set of inherent physical and chemical properties of the soil. These are not under the direct control of the farmer, and can be affected only in the long term; adversely through excessive and improper use of irrigation and other inputs and beneficially through amelioration measures. Some of these are affected by the action of others such as neighboring farmers, but we will neglect these effects.

The soil quality is affected by the farmer's actions, the levels of inputs chosen and the crop grown. One should also note that farmers adapt their cropping pattern and inputs to changes in soil quality. The economic value of changes in soil quality can be considered as the difference in the present discounted values of two profit streams.

We can characterize a farmer's behaviour as one which maximizes his discounted profits.

$$\text{Maximize } V = \sum_{t=1}^{\infty} (Py_t - C(x_t) / (1+\rho)^{t-1} \quad \text{(B.1)}$$

such that

$$y_t = f(x_t) \,.\, g(Q_t) \quad \text{(B.2)}$$

and

$$Q_{t+1} = q(x_t, Q_t) \quad \text{(B.3)}$$

$$Q_1 = \overline{Q}_1$$

Here P *is vector of prices of outputs*

C is vector of costs of inputs

y is vector of outputs

x is vector of inputs

Q is vector of soil quality parameters, and

ρ is discount rate.

Note that $Q_{t+1} = q(x_t, Q_t)$ relates inputs and current soil quality to next period's soil quality.

If we can estimate both Equations (B.2) and (B.3), the yield function and the soil quality feedback function, we can characterize farmer behavior. We

assume a stationary state in which he grows only one crop (or crop rotation) year after year. Under this assumption, the soil quality will not change from year to year and $Q_{t+1} = Q_t$. Similarly x_t and y_t would also not change.

The value of maximum V call it V^* in equation (B.1) will then be the value of soil. In the stationary state where prices, costs, inputs and outputs do not changes, under some simplifying assumptions V^* can be written as difference of two functions

$$V^* = h_0(y) - h_1(x) \quad \text{(B.4)}$$

Since both y and x are functions of soil quality $g(Q)$, we can write V to a first degree approximation as

$$V^* = W_0\, g(Q) - W_1 g(Q) \quad \text{(B.5)}$$

$$\text{i.e.} \quad V^* = [W_0 - W_1] g(Q) \quad \text{(B.6)}$$

This also implies that the relationship between the value V^* of the soil when soil quality parameters are given by a vector **Q**, and the value V_1^* corresponding to a vector $\mathbf{Q_1}$ is as follows.

$$\frac{V^* - V_1^*}{V^*} \approx \frac{g(Q) - g(Q_1)}{g(Q)} \quad \text{(B.7)}$$

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and

$$Q_{t+1} = q(x_t, Q_t) \quad \text{(B.3)}$$
$$Q_1 = \overline{Q}_1$$

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y is vector of outputs

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ABOUT THE BOOK

How do we measure and value the degradation in air, water, forests and fishing resources? How does the abatement expenditure in general and loss in health, productivity and property / wealth in particular impact sustainable income? Starting from the system of national accounts (SNA), how does one incorporate and internalise environmental concerns in the context of developing countries' economies? This monograph explains how new challenges posed by environmental stress can be addressed using environmental economics and in particular, Integrated Economic and Environment Accounting.