Ind. Jn. of Agri. Econ.
Vol. 56, No. 3, July-Sept. 2001

SUBJECT I

VALUATION OF NATURAL AND ENVIRONMENTAL RESOURCES: METHODOLOGY AND ESTIMATION

Valuation of Natural Resources: What Have We Learnt from Indian Experience?*

Gopal K. Kadekodi†

I

INTRODUCTION

In a conference of Agricultural Economics, why to talk about valuation of natural resources? This question is nothing new. It was constantly raised from the time of Kautilya, Confucius, Adam Smith (1776), Ricardo (1971) and now Hotelling (1931), Boulding (1970), Arrow and Fisher (1974), Hicks (1939) and many others. Kautilya, in his book *Arthashastra*, on the Indian economy almost about 1850 years ago, had drawn a distinction between different types of forests as 'productive and non-productive' forests from the point of view of what present day literature labels as 'use and non-use values' of resources.[1] Almost around the same time, about 300 BC back, Confucius, a great Chinese thinker, was also talking about value and price. While talking about production, consumption and pricing, he argued for 'many producers and a few consumers'; the former to be active and the latter to be thrifty; he asked the producers to wait until a proper price is offered.

Very fundamental to understand natural resources is to draw the line between value and price. Value of a commodity is a complex entity based on a theory, a philosophy and concepts of rationality. The theory can be utilitarian or intrinsic. The *philosophy* can be existence (say, right to exist). The *rationality* can be equity (say, inter- and intra-generational), or pure market clearance. Economists capture the value through a concept of 'willingness to pay' by the consumer, user, non-user, or people at large. For various reasons this value is not always revealed by people. Price for a commodity (or service) on the other hand, is based on a principle of scarcity. Scarcity commands price. It reflects a balance between what a buyer or a consumer is 'willing to pay' and a seller is 'willing to accept'. This is commonly (or sometimes loosely)

---

* Keynote paper.
† Research Professor, Centre for Multi-Disciplinary Development Research, Dharwad-580 001 (Karnataka).

called supply-demand analysis. When it comes to natural resources, many have no market; hence they may not have a price. But they may still have a value. Most of them have significant divergence between value and price. A textbook example of a natural resource having value but not a price is air. Under certain special conditions, the value can also be equal to price, and vice versa. A textbook example on this is land (both in the Ricardian and neo-classical sense).

One does not have to make an argument on natural resources that they are to be valued mainly because they are also resources, just as labour, land and capital which classical economists talked about as the basic factors of production. There are at least six other reasons for valuing natural resources separately. Firstly, there is the situation of *missing market*. In the absence of market, values of goods and services are not revealed. For instance, there are no markets for ecosystem services such as nutritional cycle, watershed functions, carbon sequestration, temperature control, soil conservation, etc. Secondly, even if there are markets, they do not do their job well. For instance, market may be a regulated one. There may be restrictions on one's entry into it either to buy or sell. An example of entry barrier is 'the State Forest Trading Corporations' having the exclusive rights to sell forest products. An example of regulated market is *kendu* leaves prices fixed by the co-operatives in Madhya Pradesh. One may say that there is a market for carbon sequestration. But the so-called 'market for carbon trading' is very restricted and regulated by international politics and agreements such as Bassel Convention on Climate Change. Thirdly, for most natural resources, it is essential to understand and appreciate its alternatives and alternative uses. For instance, alternative to fuelwood can be kerosene. Alternative uses of bhabbar grass can be for making ropes or pulp making in a paper mill. Because of these, alternative value or opportunity costs are also relevant. Fourthly, uncertainty is involved about demand and supply of natural resources, specially in the future. Most economic markets capture, at best, the current preferences of the buyers and sellers. But when it comes to natural resources, there are several types of uncertainties about the future demands and supplies. Some of them can be due to technical and demographic changes. Therefore, valuation beyond the present is also necessary as an option. Fifthly, governments may like to use the valuation as against the restricted, administered or operating market prices for designing natural resource conservation programmes (including inviting external donor agencies and corporate sectors and for negotiating carbon credits and so on). Finally, in order to arrive at natural resource accounting, for methods such as Net Present Value methods, or for cost-benefit analyses, valuation is a must.

What is it that the natural resources do to the society for which they are to be valued? Basically, they perform a large number of environmental services and ecological functions that a society enjoys (Pandit, 1997). Examples are clean air (e.g., through carbon sequestration), ecological balance (e.g., balancing the dependency between bacterial, animal, plant and aquatic life systems), nutritional recycling (e.g., natural assimilation of waste, nitrogen cycle), security (e.g., assuring non-diminishing future consumption rates), aesthetic beauty (e.g., flora and fauna of forests, water bodies, snow-bound mountains), etc. These are in addition to the known economic functions such as energy supply from fossil oil and solids, timber and non-timber products from forests and so on. Many of these are instances of non-marketed and non-use functions performed by natural resources.

Some of the pioneers in the last century who looked at valuation of natural resources were Grey (1914), Hotelling (1931), Lotka (1956). Lotka concentrated on valuing life within the framework of biological species. Grey talked about the rent on extracted resource subjected to exhaustibility. Hotelling basically investigated the effects of depletion on welfare. He argued that the optimal rate of extraction of an exhaustible resource is such that the (net) resource price or shadow cost would rise at the same rate as the discount rate. In a limited sense, he was able to link the value of a natural resource with the discount rate, which is an important parameter in national income accounting. More recently, El Serafy (1989) has provided rules for charging rent for exploiting resources at the rates different from the sustainable ones. We will have referred later on, to many other prominent contributors to this field of valuation. Recently, there has been considerable amount of research on valuation of natural resources, particularly concentrating on non-marketed and non-use situations (Maler, 1991; Dasgupta *et al.*, 1994; IIED, 1994; Freeman, 1993; Hanley *et al.*, 1997; Mitchell and Carson, 1989).

Today more and more complex issues relating to valuation of natural resources are analysed, involving issues such as exhaustibility versus renewability (Hartwick, 1990), externality associated with natural resources (Perrings, 1995), inter-generational use (Howarth, 1991), development versus preservation use of resources (Fisher and Krutilla, 1985), defensive versus preventive measures (Aronosson *et al.*, 1997) and many more. The literature is also rich with estimation methods for valuing degradation, depletion and other environmental functions (Hartwick, 1992; Hultkrantz, 1991; El Serafy, 1989; Brandon and Hommann, 1995; Mitchell and Carson, 1989). Further progress has also been made on integration of values of natural resources with the usual income accounting, use in cost-benefit analysis and several other policy making (Dasgupta *et al.*, 1994; UNEP, 1993; United Nations, 1993; Parikh and Parikh, 1997).

This paper is an attempt to take a tour of existing theoretical nicety and methods of valuation. While doing so, selected examples of estimation and issues around them are also presented. By no means, this paper is a survey paper on 'Valuation of Natural Resources: A State of Art', not even a complete exposition of any select list of valuation methods (with all the theoretical background, steps involved in estimation, highlighting the limitations, and citing examples of case studies, etc.). Instead, it is hoped that the paper gives ample opportunity to open the discussion on the relevance of valuation methods on natural resource related agricultural economics.

II

VALUATION SHOULD BEGIN FROM ECOSYSTEM FUNCTIONS OF NATURAL RESOURCES

In the most fundamental way, when it comes to natural and biodiversity resources, the genetic diversity, rarity, specie specificity, endangeredness and many such attributes of flora and fauna should be valued as much as the 'Use and Non-Use' values of which the economists are familiar with. But such an approach may lead to a dead end to the question of valuing natural resources.[2] Quantification and measurement on these are quite difficult, apart from ambiguity in identification and definitions on them. One can take an ecosystem approach instead. Ecosystems are noticeable, observable and to some extent measurable. Ecosystems have three distinct characteristics in the context of *valuation*. They are the 'existence, intrinsic and option' values. By nature, all species have the right to exist. Apart from this existence concept, there is a very high degree of dependency between them (which can not, perhaps be captured through economic production functions). That brings in them some intrinsic values. Therefore, one may make a loose argument that the intrinsic value also includes existence values. Then, they all have long run options of use or non-use.

The intrinsic value (values in themselves and, nominally, unrelated to human use) may be unique for all societies. But different societies look at them differently from social perspectives, depending upon their social values and relevance. Value to a society depends upon many things, besides its ecological significance. Therefore, a basic distinction is commonly made between an **Intrinsic value** (implicitly including existence value as well) and **Economic value**. Intrinsic values *are* relevant to conservation decisions on natural resources, but they generally cannot be easily measured (Pearce and Moran, 1994). However, valuing natural resources should not be restricted only to people's preferences (e.g., willingness to pay) for the 'economic values' but can also be extended to capture the 'intrinsic values'. Therefore, it is important to recognise the need to reach at intrinsic values as well.

Closest to existence, intrinsic and option values of natural resources is the *approach of ecosystem functions* that biological resources perform and their valuation as non-use values. The ecosystem function approach (see Figure 1) proposes to value the major functions that they perform, yet no organism in terms of the attributes such as rarity, specie specificity, diversity, and endangeredness mentioned earlier need to figure individually. This can help us avoid the apprehensions that both ecologists and economists have in general, about the value of an individual plant or animal species (Flint, 1992). The logical approach is to assign value to the ecosystem uses/functions as a whole, rather than its individual components that constitute it. In the process, the constituents will automatically get reflected and accounted for. However, not all of the ecosystem functions can be valued either.

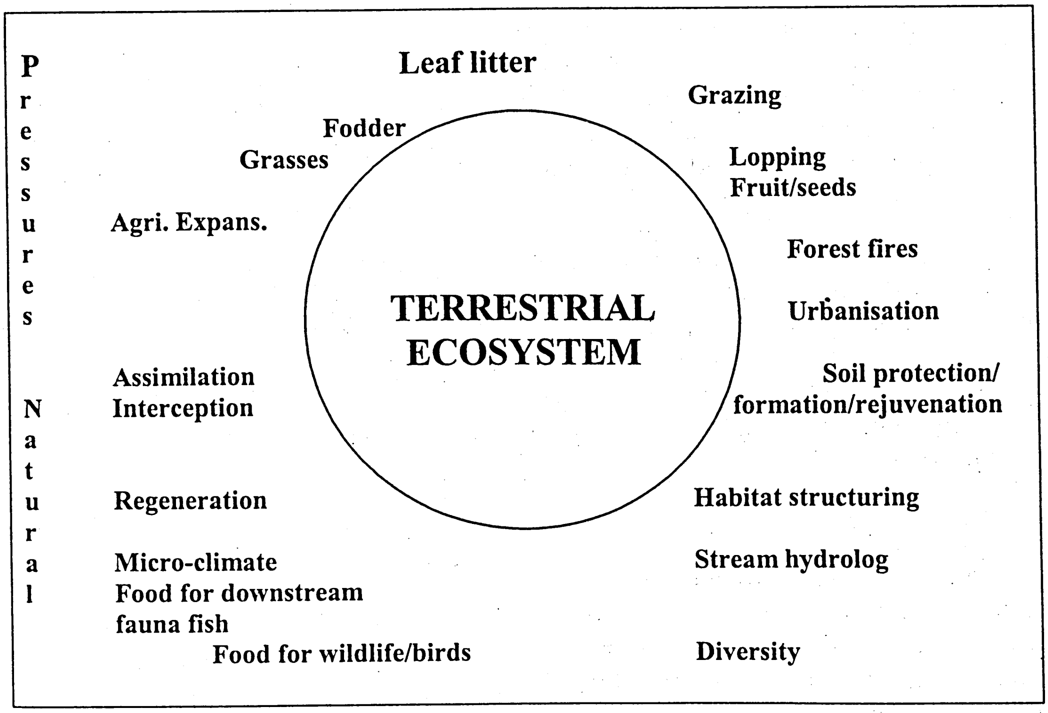

Figure 1. A Simplified Summary of Anthropogenic Pressures on a Terrestrial/ Forest Ecosystem and Its Natural Functions

Source: Pandit (1997).

III

TOWARDS AN INTEGRATION OF ECOLOGICAL AND ECONOMIC VALUES

Keeping Figure 1 in mind, there are *basically three approaches to valuation* under which we can classify the different techniques that have been evolved by economists and ecologists: In doing so, both the ecological values and economic values are to be accounted together.

(A) *Market valuation of natural resource stocks and use:* Under this category, market prices play an all-important role in the determination of the value of the resource in question.

(B) *Maintenance cost of natural asset depletion and quality degradation:* Costs that are required to maintain the resource in question in their pristine state, as they should be in their natural form shall be termed as Maintenance cost. The methods of valuation under this can be divided into (a) *objective valuation technique, and (b) subjective valuation technique.* Techniques under this category can be broadly categorised as 'replacement or repair cost', or 'treatment or pollution abatement cost' approaches.

(C) *Contingent and related valuations of welfare effects and environmental degradation:* This involves valuing a resource by putting a monetary value on the response of the people affected by the change in the state of the resource. It may even include untreated or un-noticed resources. This category involves methods like 'loss of earnings' or contingent valuation approach.

Under one or other approaches mentioned above, a concept of Total Value (TV) is developed after a great deal of discussion and exchange of ideas among the *pundits*. Basically, it is understood that natural resources provide several Use values and Non-use values to enhance human welfare and provide sustainability to all species. Conceptually, it is the sum of Use Values (UV) and Non-Use Values (NUV) which constitutes the Total Value. Some brief elaboration of these may be recounted from the literature.[3]

Use Values (UV)

Natural resources provide a variety of goods and services to the users for their current or future benefits or welfare. Hence they are said to have use values. Examples are, use of fuelwood from forests, minerals from the earth, water from rivers or underground, non-timber forest products (NTFPs) from forests and so on. The current use (consumption) of these goods and services can be either direct or indirect. Society also has the *option* of postponing any decision on the use of any natural resource. Accordingly, the use values can be further broadly classified into three groups: *direct, indirect and option values*.

Direct use values (DUV)

Direct use value can be either consumptive or non-consumptive. They refer to the current use (consumption) of the resources and economic services provided, directly by natural and biological resources. Examples are use of timber and non-timber forest products (NTFPs) and services. Forests provide fuelwood, fodder, medicinal plants, fruits, poles, etc., to the people particularly local communities and thereby generate direct consumptive use values. Recreation (e.g., tourism to wildlife sanctuaries or Himalayan glaciers, mountains), etc., are examples of direct non-consumptive use values, i.e., pertaining to those outside of the locals. While viewing elephants in wild (a case in ecotourism) is the best example of direct non-consumptive use, hunting elephants for ivory is, on the other hand, a direct consumptive use.

Of all types of values, perhaps the direct consumptive use value is substantial, at least when it comes to land, forest and water resources in India. This is because of land and water being basic to living, and forest dependency being quite high. In many parts of the world wild foods constitute still over 40 per cent of the peoples' consumption, and about 80 per cent of medicines come from plants and animals.

An alternative to *'consumptive use value'* is the *'productive use value'*. It constitutes values of products that are harvested and sold in commercial markets, at both the national and international levels. They include construction timber, fuelwood, fish and other marine products, medicinal plants, fibres, honey, bees wax, natural dyes, natural perfumes, plant gums, resins and many others. Wild species are collected for use in scientific and medicinal research and agricultural breeding.

Indirect use values (IUV)

Indirect use values generally are referred to the ecological functions that natural resource environments provide, but without harvesting, depletion or degradation. It can be broadly classified into three groups: watershed values, ecosystem services and evolutionary processes. Watershed values include flood control, regulation of stream flows, recharging of groundwater, effect of upstream or downstream, etc.; the ecosystem services include fixing of nitrogen, assimilation of waste, carbon sequestration, gene pool, etc.; and evolutionary processes include global live support, religious, cultural and aesthetic concerns, biodiversity preservation, etc.

Natural environments and landscapes have been the inspiration for many works of art and literature. Traditional communities everywhere continue to find their closest cultural and spiritual links in nature. The peace and solitude offered by these environments have enabled even many 'modern' people to seek spiritual enlightenment and solace. Many species serve as early warning systems of environmental quality. Lichens are a good indicator of air quality, and molluscs of water quality. By careful monitoring we can take the required actions to prevent the pollution from endangering human life. In some sense, all these are examples of indirect-use values.

The educational and scientific values of natural landscapes are enormous. The extinction of species and destruction of habitats will limit our efforts to explore nature and understand its implications for the human knowledge and scientific system. They also constitute indirect-use values.

Non-Use Values (NUV)

Non-use values (NUV) are entirely different from use values and are generated without any direct link with the use of natural resource under question. Essentially, the existence (or intrinsic) values, cultural and other societal values form the non-use values. An example can be the kinds of values people of a southern state, say Kerala, will put for the Himalayan mountains. These values are often revealed through people's perceptions and concerns towards conservation, culture, aesthetics and so on. For instance, *Existence values (EV) and Bequest values (BV)* are the two significant non-use values of forests.

Bequest value (BV)

The bequest value originates when people are willing to pay to conserve a resource for the use of future generations. By doing so, these people do not have an intention to 'use' the benefits during their own life span, but are bequesting those benefits for the future generations (Swanson and Barbier, 1992).

Existence value (EV)

Existence value is a concept associated with people's willingness to pay simply for the pleasure they derive from knowing that a natural area is preserved or particular species of flora and fauna are retained irrespective of any plans they may have to hunt, observe or otherwise use these resources (Swanson and Barbier, 1992). People's willingness to pay for the preservation of endangered species is an example of existence value.

Option value (OV)

Option value (OV) relates to the welfare benefits of conserving natural assets including biodiversity for being able to use them in the future, irrespective of their current use. It refers to the benefits received by retaining the option of using a resource (say, a river basin) in the future by protecting or preserving it today, when its future demand and supply is uncertain. Take the example of Narmada river basin. The option value here is the amount that individuals would be willing to pay to postpone the decision on building a dam on the river, or any other future use. Here, people do not have an intention to use the dam now but the same use may emerge in future. However, there is a view that option value and quasi option value are generally considered as future use values (Dixon and Shermian, 1990).

An illustration of total value is presented in Box 1.

Box 1. Total Value of Natural Resources

Use values			Non-use values
(1) Direct value	(2) Indirect value	(3) Option value	
Sustainable timber; Non-timber forest products; Recreation and tourism; Medicine; Plant genetics; Education; Human habitat	Watershed protection; Nutrient cycling; Air pollution reduction; Micro-climatic functions; Carbon store; Biodiversity	Future use as per (1) and (2)	Intrinsic, Existence values: Cultural, religious, and heritage values; Biodiversity

Source: Pearce and Moran (1994).

IV

METHODS OF VALUATION

Beyond the concepts of values, is the question of estimating them in specific situations. Alternative methods can be considered to arrive at the same value concept.[4] However, the appropriate method to be used will have to be based on some sound economic theory.

One can make cases for three different situations: (i) When a market for a natural resource exists; (ii) When market for a substitute or surrogate exists; and (iii) When no market and no substitute or surrogate exists.

Whenever market exists for any natural or environmental resource, the prices as revealed from the market can be an indicator of the value or benefit from those resources. The basic economic concept behind the market based values is the 'Willingness to pay' (WTP) by the demanders, who reveal their preferences based on their income and other considerations (Samuelson, 1948). Examples are timber, mineral or water prices (wherever water market exists), or willing to pay a cess to locate a public park. An alternative to enjoy the environmental benefits can also be one of foregoing the benefit and receive something else in exchange, say, an income or compensation. Then, such payments as acceptable to the people is termed as 'Willingness to Accept' (WTA). The literature on this aspect of measurement of value through WTP and WTA is quite rich (Knetsch and Sinden, 1984; Freeman, 1991; Kahneman and Knetsch, 1992; Shechter, 1995).[5]

Before we proceed to the elaboration of the WTP and WTA, some basic assumptions behind the methods should be clearly understood and questioned. The starting point for this is economic theory of consumer preferences. Consumers are supposed to be individuals, not being influenced by 'inter-personal comparison'. In that sense, their valuations are 'private valuations'. But when it comes to environmental and natural resources, many of them are public goods (Kahneman and Knetsch (1992 b). People are then supposed to express their preferences as citizen. This question will be more relevant when we return to the issue of valuing public goods such as national park. Do we have good theories of valuing public goods? Not specifically on this issue (Blamey *et al.*, 1995).

Willingness to pay does not necessarily mean the actual price which an individual (or a society with some special characteristics) will be willing to pay for the current rate of its purchase. It all depends upon the shape of the demand curve (or the preferences).[6] As shown in Figure 2, the amount of money income BC (i.e., willing to give up an income from M_0 to M_1) which an individual is willing to pay in order to enjoy $E_0 - E_1$ of an environmental good or facility, but staying at the same old preference curve U_0 is the estimate of maximum marginal willingness to pay for a marginal environmental gain. This is the Hicksian compensated consumer surplus (Hanemann, 1991; Shogren *et al.*, 1994). Similarly, GF can be argued to be the estimate of willingness to accept a marginally lower environmental good or service. It can be further shown that only under a perfect substitution situation between income and environmental good, the WTP and WTA would be equal for the same level of marginal environmental change. With lesser and lesser degree of substitution, the two would differ, which is perhaps is the real life situation in India and elsewhere.[7]

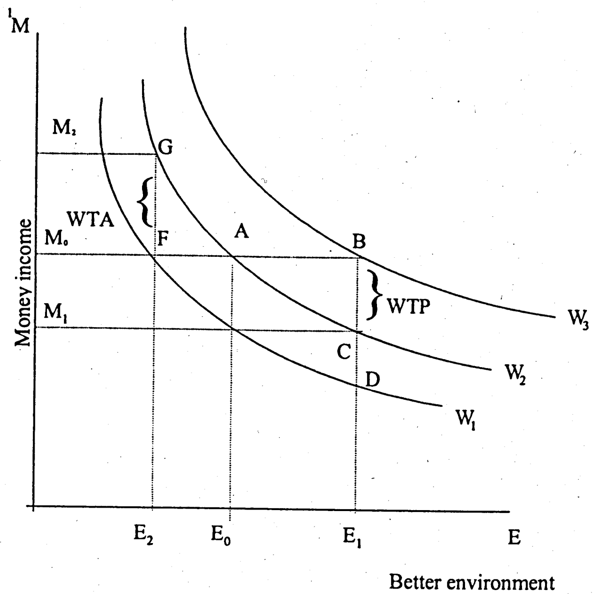

Figure 2. Economic Rationale for Willingness to Pay and Accept

What does one do if there is no market for a particular use of the resource under question? But the resource may have alternative uses with revealed market prices or may have alternative resources to substitute for. Examples are market for fuelwood may not exist for household consumption, but it exists for industrial uses. Or there are substitutes such as kerosene for fuelwood in household uses. Then, other methods are possible. Methods such as opportunity or replacement costs basically draw upon arket data and information on prices and values for such alternative, replacement or substitute. Surrogate prices are hypothetical market prices taken from such goods and services which are close substitutes for those resources. A good example can be the value of herbal medicinal plants to be the prices of non-herbal chemical based products such as synthetic creams or perfumes.

What if there are many substitutes, or replacement possibilities? Economic theory can also provide information on values for resources having many alternatives or substitutes. The shadow prices are supposed to reflect the optimal values of resources, by taking into account all those alternatives and their combinations. These can be derived only from an empirical model of optimisation of consumption or welfare, in which the resources enter as inputs. It may be possible to derive the shadow price of water or minerals in a model of production based on such resources.

How to go about valuing resources for which there are no markets and no surrogates either? It is here that alternative user or non-user based methods are to be devised. The fact that people do value them, gives some clues on devising an indirect method of arriving at those values. The user or non-user of such resources may have to be brought to a psychological situation in which she or he may agree to pay for the use or existence of the resource. Or at least state or reveal the preferences on such natural resources assuming artificially created market situation. If an individual is then made to state her or his preferences, it only reflects a statement of value, not actual value. In the literature, such an approach is called as a *stated preference method*. Contingent valuation method is one such method (Hausman, 1993). With all the developments in valuation methods, it is still not easy to assign values to natural resources especially in terms of monetary values as the role played by the various species are many, complex, and often hidden or insufficiently understood by humans.

We now list some of the most widely talked about methods with some elaborations. They are:

1. Market Valuation of Natural Resource Stocks and Changes
1.1. Market Price or Consumer Surplus Approach
1.2. The Avoidance Cost Approach
1.3. Opportunity Cost or Substitution Approach
1.4. Shadow Price Approach
1.5. The Depreciation Method or the Net Price Method
1.6 The User Cost Method

2.1. Maintenance costing of natural asset: *Objective Valuation Method*
2.1.1. The Replacement/Relocation/Restoration Cost Approach
2.1.2. The Productivity Method
2.1.3. The Welfare Method
2.2. Maintenance costing of natural asset: *Subjective Valuation Method*
2.2.1. The Hedonic Price Method
2.2.2. The Travel Cost Approach
2.2.3. The Property Value Approach
2.2.4. The Production Function Approach

3. Contingent Valuation Technique

4. Benefit Transfer Method

Very brief accounts of these methods are presented here, leaving out the details for further reading.

1. Market Valuation of Natural Resource Stocks and Changes:

Market valuation methods are used when market prices are available for natural resources.

1.1: The Market Price or Consumer Surplus Approach is relevant only in the situations of well developed markets. Only with a good market survey on a variety of consumers it may be possible to deduce the demand curve and hence estimate the average consumer surplus or 'willingness to pay'. For most natural resources, such markets do not exist. Auction price for timber or fish may be a close example of such a market price based value (Chopra and Kadekodi, 1997).

1.2: The Avoidance Cost Approach:

This approach is used for assessing quality changes in the natural assets by estimating the cost of avoiding such changes. This method is used mainly for valuing degradation of environmental resources. For instance, if a wetland protects adjacent property from flooding, the flood protection benefit is the cost of avoiding the damage to the property by the owner by alternative methods. In the case of water and air pollution, the price is estimated on the basis of what it would cost to reduce such pollution to acceptable levels (Sankar, 2001). Sometimes these are referred to as Defensive expenditure approach, or Substitute cost method.

1.3: The Opportunity Cost or Substitution Approach:

Biological resources may have alternative use and relevance. For instance, a waterfall in a forest may mean only water to some, aesthetic beauty for someone else, yet may be a source for hydro-electricity generation for someone else. Hence there are alternative uses or perceptions and hence alternative values. Only when all the alternative values are looked into, the true value of the resources is properly understood. Secondly, only some natural resources do have alternatives. An example is dung manure (a biodiversity produce) to be replaced by chemical fertiliser in agriculture. Then, the value of this biodiversity resource can be based on the value of the equivalent chemical fertiliser replaced (Chopra *et al.*, 1990).

1.4: Shadow Price Approach

This method is appropriate only in such natural resource situation when it has several alternative uses, some of which as non-substitutable, some others are substitutable. Using a programming approach, it will then be possible to arrive at alternative values (called shadow prices) on resources with and without substitutes (Reyer *et al.*, 1999).

We now take up the case of depleting natural resources. Examples are minerals. Such resources command market prices, no doubt. But, as in the case of man-made capital, their extraction leads to depletion (equivalent to depreciation). Hence, their market price does not necessarily reflect the true value of such resources (Hicks, 1940). Only when the value of depletion is deducted from the market price, one gets the picture of the true value of the resources. There are primarily two methods for valuing such depleting resources:

1.5: The Depreciation Method or the Net Price Method:

The method is based on the Hotelling (1931) rent assumptions, which claims that in a perfectly competitive market, the price of a natural resource rises at the rate of interest of alternative investment, offsetting the discount rate. According to Hotelling, the rent defined as the difference between the price of the resource and the marginal cost of extraction, would reflect the true value of the natural resource stock. Since the resource extraction is over a long time period, discounted sum of the difference between the price and marginal cost is to be taken as the value of the resource. The choice of the discount rate is crucial here.

1.6: The User Cost Method:

The User cost method (proposed by El Serafy, 1989) is an alternative method to Depreciation method. The user cost approach does not address to the valuation of the stock or reserve but focuses on potential income that can be generated from the extraction (sales). The basic idea here is to convert a time bound stream of net receipts (R) from the sales of an exhaustible resource into a permanent income stream (X) and a 'user cost allowance' (R-X) over the lifetime of the resource. Hypothetically, this user cost allowance is to be invested for the future (just as depreciation allowance on man-made capital is supposed to be). Only the remaining amount X of the receipts should be considered 'true income'. This method thus takes into account the depletion aspects of the exhaustible nature of natural resources in valuation (TWGEVA, 2001).

2.1: Maintenance costing of natural asset: *Objective Valuation Method*

The Maintenance Cost Valuation Methods are those which involve valuing resources with the objective of maintaining them in their pristine state. Objective Valuation Methods primarily are about valuation of physical changes in the quality and quantity of resources by valuing physical damage caused by offending economic activities. There are three major categories of these methods.

2.1.1. The Replacement Method or the Maintenance Cost Method:

According to this method the value of a natural resource is determined by the restoration cost of produced and non-produced natural assets. This method defines cost of a natural resource as the cost that would be incurred to maintain the original level of the resource at the beginning. For example, the replacement cost of groundwater resources would be equal to the cost of recharge of this water to its original level (and not substituting by surface water). This approach has been widely used in the literature mainly for renewable natural resources such as water and fishery (Bhatta, 2001).

2.1.2. The Productivity Method:

This method estimates the environmental costs in terms of loss of production arising from depletion, say, of water resources, that is likely to reduce productivity in crop cultivation by (a) reducing the area under cultivation, (b) changing cropping pattern or (c) reduction in the yields. An example can be of degradation of land due to say soil erosion, likely to reduce yield per hectare (Parikh, 2001). Other applications can be on measuring the costs of water pollution on fish stock damage.

2.1.3. The Welfare Method or Dose-response method:

One major impact of environmental depletion and degradation is on health and welfare of people in terms of increased sickness (morbidity) and increased premature death (mortality). For example, lack of adequate water supply or non-potable drinking water may lead to increased incidence of water-borne diseases or in some cases to premature deaths. The cost of morbidity can be computed by estimating the medical expenses – expenses on medicines, admission, etc., for the patients. This cost will also include (a) loss of wages of the patients, (b) loss of wages of the attending persons to the patient as well as (c) the cost of discomfort and dis-utility (Jyoti Parikh, 2001; Dasgupta, 2001). These can be estimated through a primary survey (the last is difficult to measure, one can use contingent valuation here). The value of premature death can be computed based on the value of a statistical life (Cousineau *et al.*, 1992), as determined by either a human capital approach or by a willingness to pay approach. The former method values on individual's life according to the net present value of his/her productivity. The willingness to pay approach measures the value which society places on an individual as distinct from an individual's wage earning capacity. The first approach tends to give a lower value than the second approach.

2.2. Maintenance costing of natural asset: *Subjective Valuation Method*

Subjective Valuation Methods measure possible environmental value as expressed or revealed in real or hypothetical markets. These methods can be broadly divided into Surrogate Market Valuation and Contingent Valuation. Surrogate Market Valuation approaches use information relating to market goods to infer the value of an associated non-market good. The different valuation techniques used here are:

2.2.1: The Hedonic Price Method or the Property Value Method or the Wage Differential Approach are different variants of similar methods. Here, the changes in land or property price due to a change in the environmental amenity is reflected in the value attached to the amenity. This method evaluates best the differential advantage obtained from extended residence in certain spatially performed locations.

Next to Option value, this is another important method relevant for natural resource conservation. It uses a related market approach and direct observations are used to value an environmental amenity. This method is based on the assumption that the value of a resource is related to net benefits derived from it. The basic premise is that consumers can reveal their choice of consumption of environmental goods, through their choice of related market goods and services (typically property prices or wages). A person may choose a home where air/environment is good, and may pay more for this environment (for example, fresh air, vicinity of parks/rivers etc.). The Hedonic price method employs statistical techniques to isolate environmental values, which contribute to an observed difference in product prices. For examples of most recent application of this technique in India is by Golan and Evanson (1988) and Verma (2000).

2.2.2: The Travel Cost Approach: The Travel Cost Method (TCM) is typically used to capture the recreational value of sites, such as national parks and sanctuaries. Sometimes, though less often, it has also been applied to problems like finding the value of collected forest products (not routed through the markets) for villagers, by examining the travel and time costs involved in collecting them. In general, the method can be used in situations such as changes in access costs for a recreation site; elimination of an existing recreation site; addition of a new recreation site; changes in environmental quality at a recreational site, etc.

Here the expenditure incurred on visiting a site is treated as a revelation of consumer's preference for the environmental services provided by it, and derives the value placed on these services. The basic philosophy is to use the cost of travel as surrogate for the willingness to pay for using the recreation site. Travel costs would include actual transportation costs, fees paid at hotels and at times the opportunity cost of travel time spent on journey, as a proxy for asset value of the recreation site (a non-market asset). It is most commonly used for assessing the value of national parks meant for preservation of flora and fauna (Chopra, 1998; Hadker *et al.*, 1997).

2.2.4: The Production Function Method: The production function method or the alternative technology approach is used for valuing indirect ecological function of environmental assets. The first method views the contribution of a natural resource to economic activities in terms of substitute inputs. For example, soil conservation may result in saving the amounts spent on chemical fertiliser (Kumar, 2000). The alternative technology approach can also be classified as a cost based valuation as the contribution of the natural resource is viewed in terms of the saving effected by not having to resort to the alternative technology. Soil conservation in upstream forest, for example, results in a saving in the cost of de-silting of downstream water bodies using mechanical dredgers.

3. Contingent Valuation Technique:

Contingent Valuation Methods are used when markets do not exist for environmental resources (Mitchell and Carson, 1989; Hausman, 1993). The valuation is done here in hypothetical markets. The valuation task here is to determine how much better or worse off individuals will be as a result of a change in an environmental resource/asset. This is computed by asking how much people are willing to pay for an environmental benefit (WTP) or how much are they willing to give up to have a specified environmental quality improvement happen. This method is also used in terms of how much people are willing to accept as a compensation (WTA) for an environmental resource. The price that people are willing to pay (a weighted average is computed) is taken as the price, and valuation of the asset or the resource is done using this price. This approach is used for valuation of wilderness, as well as of common environmental facilities like forests, common lands, common water bodies, etc. (Kadekodi *et al.*, 2000; Manoharan, 1996; Maharana *et al.*, 2000).

A particular advantage of CVM over other valuation techniques is that the method can be designed specifically to identify non-use values. CVM responses of users of a resource (e.g., park visitors who are currently in a park) are statements of their total economic value. When CVM is conducted among populations who are or who never have been users, then their responses can be interpreted as non-use value statements.

4. *Transferring Benefits Theory and Practice:*

It is often difficult to actually carry out fresh studies on the valuation of natural resources in some specific situations, say, glacier mountains of Himalayas. This is hardly surprising since environmental valuation methodology is still developing and most of the existing studies concentrate on keystone biological resources. Moreover, any fresh study may be costly and time consuming to conduct. One short cut to overcome this information gap is to borrow and transfer valuation/benefit estimates from existing studies to the new or subject study site, an approach known as *benefits transfer*. This approach is essentially the second best option when data are un-available. There are serious concerns over the legitimacy of transfer of values from one site to another for various reasons:

The reliability of the original estimate itself is doubtful. The similarity of the environmental characteristics of the target site to which the value is applied can remain doubtful. In essence it is difficult to separate the reliability of the resulting numbers from the underlying or original studies from which they are drawn. There is every likelihood of any resulting bias in benefit estimates which are a product of bias in the original studies and those arising from the transfer process itself. However there are a number of improvements in the method in recent literature (Brouwer, 2000).

V

SOME ISSUES REGARDING VALUATION METHODS

Valuation techniques developed so far are not entirely able to capture the exact value of natural and environmental resources. Non-market products of nature, which are largely used by indigenous people, are difficult to value since there does not exist a market for these products. In cases such as these, there is a strong need to device mechanism for valuing these products that are not marketed. Among them are sacred and religious values (Chandrakanth and Nagaraja, 1997).

There does not exist a clear ranking of methods of valuation that are known so far. All methods are not equally relevant for all resources either. Each technique requires a variety of assumptions depending upon the method being applied and of course the resource being considered for valuation. What clearly emerges from the various studies of the use of valuation techniques is that key modeling assumptions do have an important influence on estimates of valuation. The inconsistencies in the maintained assumptions of both direct and indirect methods, as they were applied to each of the problems considered in comparative evaluations, would seem to be sufficient to account for any observed difference between them.

There is an unresolved methodological puzzles that still remain and relates to the consistency of different valuation techniques. Alternative techniques can be categorised as those that are based on revealed preference and stated preference. Market price based mechanism can be grouped in the first category and CVM and related techniques can be categorised into the second type. A fundamental question is about additivity of revealed preference values to stated preference values to arrive at a total economic value. A good example is about additivity of use value of timber (a revealed preference value) to nutritional cycling value (a stated preference value). However, there seems to be some kind of strong correlation between these values as shown in Figure 3 for a sample of studies.

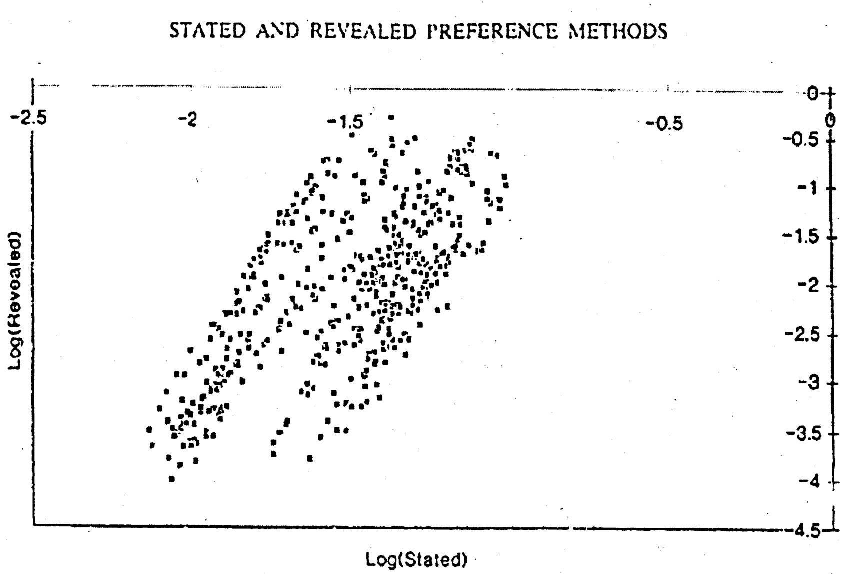

Figure 3. Stated Versus Revealed Preference Predicted Probabilities

Source: Adamowicz *et al.* (1994).

A further problem that arises while valuing a resource is on additivity of different kinds of values. It is often debated that such kinds of values accruing from a resource constitute a part of the so-called total economic value. Will different values assigned to a particular situation or resource be double counting for total economic value? See Box 2 for an illustration on this. However, on a practical basis, all values accruing from a resource cannot be accounted any way; and hence there seems to be an agreement to add whatever is accountable. But such a state of current knowledge makes this valuation a somewhat hazardous enterprise. So, as has been said before in our discussion on the techniques for valuation, it is the assumption in the methods being applied that account for the difference in the results between two estimates which might have been arrived at using two different methods. And the choice of a method for valuation is dependent upon the resource in question, the data availability and the judgment of the evaluator. It is the last, which is the cause of all contentions.

Box 2. Case of Possible Double Counting of Ecosystem Values

Take as an illustration, the case of ecosystem value of coral reefs in an area of 62 million hectares.

The following are independent ecosystems and their estimated values per hectare per year.

Disturbance regulation	$ 2,750
Waste treatment	$ 58
Biological control	$ 5
Food production	$ 220
Raw materials	$ 27
Total ecosystem value	$ 3,060

But, independently, there is also an estimate of the Recreation value, based on Travel cost method.

Recreation	$ 3,008
Total	$ 6,068

Note that the value of ecosystem services is just about the same as that of Recreation benefits (based on Travel cost method).

Should the ecosystem value be added to the recreation value?

Is it n't true that the recreation value is just about the total of ecosystem values? Is it not true that recreation value is due to all those ecosystem values? Have we not double counted the ecosystem values of the coral reef?

A reference has already been made to the value as reflecting an individual or private value as against that of a citizen. Since a large number of natural resources are of the nature of public goods, the economic methods of WTP and WTA are not directly appropriate, unless there are methods of arriving at social aggregates of values (Sen, 1970).

Are there alternatives to valuation then? The physical and monetary valuation of a resource is of utmost importance in order to value natural resources. The actual valuation of any resource is contingent upon many aspects. An alternative way to view the problem of environmental degradation and their valuation is to look at them from the perspective of different stakeholders, in terms of (a) the activities of the stakeholders which affect the resource, (b) the resulting change in the environment as a result of the activities – the stressors, and (c) the impacts of the change in the state of the environment impacts receptors due to change in exposure to stressors and the response of individuals to impacts. The development of valuation based on stakeholders' approach is relatively new but quite promising (Singh and Hegde, 2001).

There is always a question on the valuation methodology vis-a-vis cost-benefit analysis. It can be argued, it is not really so, that they are two alternatives. Rather, they are mutually dependent method. After all, benefits and costs comprise of both the physical attributes and their values.

Apart from these general issues, there are a large number of specific issues pertaining to individual methods. The debate and research in many of these are very vital for developing more and more precise methods of valuations, reflecting both economic and ecological values.

VI

SOME EXAMPLES OF STUDIES ON VALUATION IN INDIA

In India, attempts to estimate economic values of natural resources have been substantial by now. Though it all got started with forest based resources, the arena has moved to wetlands, water bodies, wildlife, marine life, minerals, pollution and many more.

A good number of studies attempted to value forest benefits and services (timber, NTFP, ecotourism/recreational benefits). Most of the studies have used Contingent Valuation Method (CVM) and Travel Cost Method (TCM). The total values as well as their components vary considerably across locations, which is understandable from the fact that India has sixteen major agro-climatic and eco-regional configurations. For instance, the value estimated for a particular recreational feature for local residents (e.g., Periyar) can not be compared with the value derived on the basis of WTP of international or urban visitors to a park located near a mega city (e.g., Keoladeo National Park in Delhi or Borivli National Park in Mumbai). Similarly, some natural areas have unique features and are attached with special values (e.g., The sacred lake in Sikkim Himalaya).

There are also many attempts to value various watershed benefits. In some cases, specific watershed functions (e.g., value of water supply in Almora) are estimated. In other cases, economic value of various watershed benefits is estimated collectively (e.g., in Sukhomajri village). Methodologies such as reduced or changed cost of alternative technologies, replacement cost approach, opportunity cost, productivity (loss or gain in productivity approaches, CVM, etc., have been applied to estimate various watershed benefits.

Some methodological studies are now available on valuation of water pollution (based on willingness to pay for cleaning polluted or waste water), e.g., Ganga Action Plan, or water pollution due to leather industries (James and Murty, 1998; Sankar, 2001), health effects of indoor and outdoor air pollution (Jyoti Parikh, 2001; Dasgupta, 2001), solid waste (Reyer *et al.*, 1999). Invariably, methods such as CVM, dose-response analysis are used in assessing these costs or benefits. Still lacking are good methodological studies on urban environment (transport congestion, air pollution, slum clearing, etc.).

There are not many studies on ecological valuation of Indian forests. A study by Kadekodi and Ravindranath (1997) and another by Haripriya (1999) present estimates of carbon sink values of Indian forests by analysing the inter-linkages between forestry and other sectors of the Indian economy. The studies on economic value of nutrient fixing, pollution control, and other ecological functions as result of biodiversity are limited. However, attempts have been made to derive these values by applying indirect methods to estimate aggregate values of forests/biodiversity in a particular state or region (Verma, 2000).

Studies that attempted natural resource accounting estimated several benefits of biodiversity in economic terms (Parikh and Haripriya, 1998; Chopra and Kadekodi, 1997; Verma, 2000).

Attempts to estimate option value and non-use values such as existence value and bequest value are also seen in some studies (Chopra, 1993). However, the reliability of these values in the Indian context has not been discussed extensively. A bird's view of select list of such estimates is shown in Table 1.

TABLE 1. ECONOMIC VALUE OF THE COMPONENTS OF NATURAL RESOURCES: SOME SELECT INDIAN STUDIES

Goods and services valued (1)	Annual value (2)	Location (3)	Methodology applied (4)	Source (5)
Recreation/ Ecotourism	Rs.16,197 per ha. (Rs.427.04 per Indian visitor Rs.432.04 per foreign visitor)	Keoladeo National Park, Bharatpur	Travel cost method	Chopra (1998)
Recreation/ Ecotourism	Rs.20,944 per ha. (Rs.519 per Indian visitor and Rs. 495 per foreign visitor)	Keoladeo National Park	Contingent valuation method	Murty and Menkhaus (1994)
Recreation/ Ecotourism and other benefits	Rs. 23,300 per ha. (Rs. 90 per household); (Rs. 7.5/month/household); Rs. 240 million/year	Borivli National Park, Mumbai	Contingent valuation method	Hadker *et al.* (1997)
Ecotourism	Rs. 676 per ha. (for locals); (Rs. 3.2 million total per year)	Periyar Tiger Reserve	Contingent valuation method, Travel cost method	Manoharan (1996)

(Contd.)

TABLE 1 *(Contd.)*

Goods and services valued (1)	Annual value (2)	Location (3)	Methodology applied (4)	Source (5)
Ecotourism	Rs. 2.95 million total; (Rs. 34.68 per visitor)	Kalakadu Mundanthurai Tiger Reserve, Tamil Nadu	Contingent valuation method	Manoharan and Dutt (1999)
Ecotourism/ recreational/ pilgrimage/ sacred grove	WTP for maintenance and preservation of the lake by: Local community = US $ 0.88 (Rs. 36.08) Local pilgrims = US $ 2.2 (Rs. 90.2) Resident visitors = US $ 2.5 (Rs. 102.5) Non-resident visitors = US $ 7.2 (Rs. 295.2) (Aggregate WTP = US $ 46,940 based on total visits per year (Rs. 1.92 million) Per hectare value = Rs. 1,604	Recreational value of a sacred lake in Sikkim Himalaya (Khecheopalri lake)	Travel cost method and Contingent valuation method	Maharana *et al.* (2000)
Ecotourism	WTP for the management of the park: by foreign tourists: $ 8.84; by domestic tourists: $ 1.91; by local community: $ 6.20 per year. WTP total for annual maintenance works out to $ 87,777.	Khangchendzonga National Park, Sikkim	Contingent valuation method	Maharana *et al.* (2000)
Wetland	Additional value of property around the lake is Rs. 186 per sq. ft.	Bhoj Lake, Bhopal	Hedonic pricing	Verma (2000)
Soil conservation	Cost of soil erosion: Rs. 21,583 per hectare	Doon valley	Replacement cost approach	Kumar (2000)
Soil conservation	Decline in value of land due to soil degradation is Rs. 3,510 per hectare	Haryana agricultural land	Productivity approach	Kirit Parikh (2001)
Urban water pollution	Average cost of illness per household per year: Rs. 1,094	City of New Delhi	Production function	Dasgupta (2001)
Biomass/ dung/ watershed	Value of additional dung collected due to stall feeding is Rs. 34.40 per cattle per year	Sukhomajri village	Opportunity cost	Chopra *et al.* (1990)
Water supply	Rs. 4,745 per hectare	Almora forests	Indirect methods	Chaturvedi (1992)
Water supply	Annual willingness to pay for water: Rs. 109 - Rs. 410 for irrigation purposes; Rs. 27 – Rs. 53 for drinking purposes	From glacier to Tarai mountain region of Kumaon valley	Contingent valuation method	Kadekodi *et al.* (2000)
Ecological functions (use value) for local residents	Rs. 624 per hectare	Yamuna Basin	Contingent valuation method	Chopra and Kadekodi (1997)
Carbon store	Rs. 1,292 billion (for total Indian forests) and Rs. 20,125 per hectare	Indian forests	Species-wise forest inventory data	Haripriya (1999)

(Contd.)

TABLE 1 *(Contd.)*

Goods and services valued (1)	Annual value (2)	Location (3)	Methodology applied (4)	Source (5)
Carbon store	Rs. 1.2 lakh per hectare	All-India forests	Biomass estimation	Kadekodi and Ravindranath (1997)
Urban air pollution	Statistical value of life affected: Rs. 2.87 lakhs per life; Human capital value affected: Rs. 3.83 per life	Mumbai city	Dose–response model	Jyoti Parikh (2001)
Water pollution	WTP for best quality: Rs. 500; for 1995 quality: Rs. 200; for 1985 quality: Rs. 100 (all these are median values)	River Ganga	Contingent valuation method for non-user benefits	James and Murty (1998)
Water pollution	Economic cost of pollution abatement per kilo-litre waste water per day in tanneries: Rs. 20 – Rs. 66	Tanneries in Tamil Nadu	Cost-benefit model	Sankar (2001)
Fishery resources	Willingness to pay for conservation: Rs. 859 per year on average	Coastal Karnataka	Stakeholder Analysis and Contingent valuation method	Bhatta (2001)
Watershed values (Soil conservation)	Rs. 2.0 lakh per hectare-metre of soil	Yamuna Basin	Indirect method (Reduced cost of alternate technology)	Chopra and Kadekodi (1997)
Forests in Himachal Pradesh	*The total economic value of forests in Himachal Pradesh is estimated as Rs. 1,06,664 crores which is 2.61 times the value of the growing stock. * The contribution of forestry as a percentage of corrected GSDP is 92.40 per cent instead of recorded 5.26 per cent.	Himachal Pradesh State	Total economic value approach	Verma (2000)
Forests in Maharashtra	*Contribution of forests is estimated as Rs. 35,245.65 million as against Rs. 14,080 million shown in SNA. (i.e., it is 3.56 per cent of adjusted NSDP and not 1.46 per cent recorded). *Value of depletion (difference between the value of opening stock, other volume changes and the closing stock in forest accounts) = Rs. 6.,989 million (this is 19.8 per cent of the estimated value added) *Estimated asset values of forests = 28.6 per cent of net fixed capital stock.	Maharashtra State	Physical accounting (tools employed: net price method, present value method, etc.)	Parikh and Haripriya (1998)

(Contd.)

TABLE 1 *(Concld.)*

Goods and Services valued (1)	Annual value (2)	Location (3)	Methodology applied (4)	Source (5)
Forests in Yamuna Basin	*Use value of timber: Rs. 8,279 to Rs. 18,540 per cubic-metre of extracted timber. *Annual value of main non-timber forest products (NTFPs): Rs. 7,509 per sq. km in Hills and Rs. 558 per sq. km in Plains. *Use value of ecological functions and unrecorded production: Rs. 176 per hectare in Himachal Pradesh Rs. 3,509 per hectare in Haryana Average: Rs. 624 per hectare *Value of preservation as contributing to national output: Rs. 576 lakhs per year *Household willingness to pay in rural areas for use value of forests: Rajasthan: Rs. 1,072 per hectare Uttar Pradesh: Rs. 360 per hectare Himachal Pradesh: Rs. 176 per hectare Haryana: Rs. 3,509 per hectare	Yamuna Basin	Contigent valuation method, Direct market valuation, Multi-criteria analysis and Travel cost	Chopra and Kadekodi (1997)
Iron ore	User cost per tonne: Rs. 8.63 per tonne	Goa	User cost method	TWGEVA, 2001

VI

CONCLUDING REMARKS

As one goes along more and more expounding the theoretical literature, estimates and experience in estimation, the impression one gets is that there are many more unanswered questions on valuation than what the methods can answer. But the idea is not discouraging social and natural scientists, but encouraging them to come together and get into the details of the conceptual and integrated issues of ecology and economics and arrive at the appropriate methods. In doing so, economic methods have to be further developed to internalise qualitative information coming from ecological sciences. Many of the neo-classical foundations, however good they are, cannot capture the public good characteristics of natural resources.

Some of the on-going debate and unresolved problems may be listed for future work.

Firstly, under the CVM techniques the merit and demerits of Dichotomous and Open-ended questioning should be clearly understood and resolved. In either case, there are possibilities of biases due to individuals not being responsible (or accountable) for their answers (known as embeddedness).

Secondly, the methods of aggregating the responses of the people on CVM (or, to some extent even on travel costs methods) as a reflection of citizen's responses rather than individual responses need to be developed. Statistical methods of scoring and ranking (e.g., multi-criterion approach) may have to be looked in to.

Thirdly, to what extent methods such as Benefit Transfer actually usable in real life situation? What are the specific variables and factors to be used to correct benefit-transfer estimates to suit any specific region or country? Some notable ones are per capita income or consumption, income distribution or distribution characteristics and weights, population growth, etc.

Finally, can we actually value and find ways of checking exhaustibility of natural resources in the context of development. The basic question is the controversy between preservation and development (Fisher and Krutilla, 1985; Howarth, 1991).

NOTES

1. According to Kautilya, 'productive forests' are for production and human use and for rearing elephants. Non-productive forests are those reserved "for ascetics, recreation and as wild life sanctuaries". He had even drawn a list of forest products to be accounted for. The list is remarkably exhaustive, with both timber and non-timber products finding mention. The notable ones among them are: timber (teak, pine, hardwood and sal), varieties of bamboo and reeds, creepers, fibrous plants, rope making grass, leaves, flowers for extracting colours, medicinal plants and poisonous plants. He developed an accounting method for a number of commodities and services obtained from forests and game sanctuaries. For some details of what Kautilya had dealt with respect to forest resources, attention may be drawn to *Arthashastra*, Book 2, Chapters 2, 5, 6, 17 and 18. A brief account of these in English however is available in Rangarajan (1987). He also provided a mechanism of accounting in a tabular form. Somewhat in line with the main focus of his work, a form of accounting was evolved with the purpose of helping the King to raise revenue by taxation.

2. There is good amount of thinking and contribution on this by biologists and ecologists. For a good account of these, see Wilson (1988, 1992), Shaffer (1983), Brown and Goldstein (1984), Polasky and Solow (1995), Montgomery *et al.* (1999).

3. The literature is quite rich in this area of valuation concepts, methods. A select list of literature is given in the bibliography.

4. For instance, even outside of natural resources, there is always the question of which method to use for estimation. For instance, labour can be valued in terms of (a) opportunity cost, (b) minimum wage, (c) marginal productivity, and (d) value of leisure.

5. A philosophical question is why to pay when natural resources belong to all. Does it not imply that they did not own it to start with? Secondly, why should they accept something in return (for foregoing environmental benefits) if they have not owned natural resources in the first place? See Knetsch and Sinden (1984) for such an interesting debate.

6. Only if the demand curve is horizontal, the value and price would be the same.

7. With different marginal utility of money income, different societies and sections of the societies would be willing to pay differently from willingness to accept.

REFERENCES

Adamowicz, W.; J. Louviere, and M. Williams (1994), "Combining Revealed and Stated Preference Methods for Valuing Environmental Amenities", *Journal of Environmental Economics and Management*, Vol. 26, pp. 271-292.

Ando, A.; J. Camm, S. Polasky and A. R. Solow (1998), "Species Distributions, Land Values, and Efficient Conservation", *Science*, Vol. 279, pp. 2126-2128.

Aronosson, T.; Peter Olav Johansson and Karl-Gustaf Lofgren (1992), "Deforestation and Natural Accounting", *Environmental and Resource Economics*, Vol. 2, No. 5, pp. 513-522.

Aronosson, T.; Per-Olov Johansson and Karl-Gustaf Lofgren (1997), *Welfare Measurement, Sustainability and Green National Accounting: A Growth Theoretic Approach*, Edward Elgar, Cheltenham, U.K.

Arrow, K.J. and A.C. Fisher (1974), "Environmental Preservation, Uncertainty and Irreversibility", *Quarterly Journal of Economics*, Vol. 88, pp. 312-319.

Bateman, I.J. and R.K. Turner (1993), "Valuation of the Environment Methods Techniques: The Contingent Valuation Method", in R. K. Turner (Ed.) (1993), *Sustainable Environmental Economics and Management: Principles and Practice*, Belhaven Press, London.

Bennett, J.W. (1984), "Using Direct Questioning to Value the Existence Benefits of Preserved Natural Areas", *Australian Journal of Agricultural Economics*, Vol. 28, Nos. 2-3, pp. 136-152.

Bhatta, Ramachandra (2001), "Economic Valuation of Marine Biodiversity: Framework for Analysis and Implementation", Contribution to TWGEVA (2001), *op. cit.*

Bishop, R.C. (1978), "Endangered Species and Uncertainty: The Economics of a Safe Minimum Standard", *American Wildlife Journal of Agricultural Economics*, August, pp. 685-691.

Bishop, R.C. and M.P. Welsh (1992), "Existence Values in Benefit Cost Analysis and Damage Assessment", *Land Economics*, Vol. 68, No. 4, pp. 405-417.

Blamey, R.; M. Common and J. Quiggin (1995), "Respondents to Contingent Valuation Surveys: Consumers or Citizens?", *Australian Journal of Agricultural Economics*, Vol. 39, No. 3, pp. 262-288.

Boulding, Kenneth (1970), *Economics as a Science*, McGraw-Hill Book Co., New York.

Boulding, Kenneth (1996), "The Economics of the Coming Spaceship Earth", in H. Jarrett (Ed.) (1996), *Environmental Quality in a Growing Economy*, Resources for the Future, Washington, D.C.; The Johns Hopkins University Press, Baltimore.

Boyle, K. J. and R.C. Bishop (1987), "Valuing Wildlife in Benefit Cost Analyses: A Case Study involving Endangered Species", *Water Resources Research*, Vol. 23, No. 5, pp. 943-950.

Brandon, Carter and Kirsten Hommann (1995), "The Cost of Inaction: Valuing the Economy-wide Cost of Environmental Degradation in India", Asia Environment Division, The World Bank, Washington, D. C., U.S.A.

Brouwer, R. (2000), "Environmental Value Transfer: State of the Art and Future Prospects", *Ecological Economics*, Vol. 32, No. 1, pp. 137-152.

Brown, G.M., Jr. and J.H. Goldstein (1984), "A Model for Valuing Endangered Species", *Journal for Environmental Economics and Management*, Vol. 11, No. 4, pp. 303-309.

Chandrakanth, M.G. and M.G. Nagaraja (1997), "Existence Value of Kodagu Sacred Groves: Implications for Policy", in Anil Agarwal (Ed.) (1997), *Challenge of the Balance*, Centre for Science and Environment, New Delhi, pp. 217-224.

Chaturvedi, A.N. (1992), "Environmental Value of a Forest-Almora", in Anil Agarwal (Ed.) (1992), *The Price of Forests*, Centre for Science and Environment, New Delhi.

Chopra, Kanchan (1993), "The Value of Non-timber Forest Products: An Estimation for Tropical Deciduous Forests in India", *Economic Botany*, Vol. 47, No. 3, pp. 251-257.

Chopra, Kanchan (1998), "The Valuation of Biodiversity within Protected Areas: Alternative Approaches and a Case Study", IEG Discussion Paper, Institute of Economic Growth, New Delhi.

Chopra, Kanchan and Gopal Kadekodi (1997), *Natural Resource Accounting in the Yamuna Basin: Accounting for Forest Resources*, Institute of Economic Growth, New Delhi (monograph).

Chopra, Kanchan; Gopal Kadekodi and M.N. Murty (1990), *Participatory Development: People and Common Property Resources*, Sage Publications India Pvt. Ltd., New Delhi.

Cousineau, J.M.; R. Lacroix and A.M. Girard (1992), "Occupational Hazard and Wage Compensating Differentials", *The Review of Economics and Statistics*, pp. 166-169.

Dasgupta, Purnamita (2001), "Valuing Health Damages from Water Pollution in Urban Delhi, India: A Health Production Function Approach", Working Paper No. E/210/2001, Institute of Economic Growth, Delhi.

Dasgupta, P.; B. Kristrom and K.G. Maler (1994), "Current Issues in Resource Accounting", Beijer Discussion Paper Series, No. 47, The Royal Swedish Academy of Sciences, Stockholm.

Dixon, J.A. and P.B. Sherman (1990), *Economics of Protected Areas: A New Look at Benefit and Costs*, Earthscan Publications Ltd., London.

Eiswerth, M.E. and J.C. Haney (1992), "Allocating Conservation Expenditures: Accounting for Inter-Species Genetic Distinctiveness", *Ecological Economics*, Vol.5, pp. 235-249.

El Serafy, S. (1989), "The Proper Calculation of Income from Depletable Nature Resources", in Y.J. Ahmed, S.El Serafy and E. Lutz (Eds.)(1989), *Environmental Accounting for Sustainable Development*, The World Bank, Washington, D.C., U.S.A.

Fisher, A.C. and J.V. Krutilla (1985), "The Economics of Nature Preservation", in A.V. Kneese and J.L. Seeney (Eds.) (1985), *Handbook of Natural Resources and Energy Economics*, Vol. 1, North-Holland Publishing Co., Amsterdam, pp. 165-189.

Flint, M. (1992), "Biological Diversity and Developing Countries", in A. Markandya and J. Richardson (Eds.) (1992), *The Earthscan Reader in Environmental Economics*, Earthscan Publications Ltd., London.

Freeman, A.M. (1979), *The Benefits of Environmental Improvement: Theory and Practice*, The Johns Hopkins University Press, Baltimore.

Freeman, A.M. (1991), "Valuing Environmental Resources under Alternative Management Regimes", *Ecological Economics*, Vol. 3, pp. 247-256.

Freeman, A.M. (1993), *The Measurement of Environmental and Resource Values: Theory and Methods*, Resources for the Future, Washington, D.C., U.S.A.

Gabel, L.H.; J.F. Shogren, S.Y. Seung, D.J. Hayes and J.B. Kliebenstein (1994), "Resolving Differences in Willingness to Pay and Willingness to Accept", *American Economic Review*, Vol. 84, No. 1, pp. 255-270.

Garrod, Guy and Kenneth G. Willis (1999), *Economic Valuation of the Environment: Methods and Case Studies*, Edward Elgar, Cheltenham, U.K.

Golan, D. and R. Evanson (1988), "An Application of Hedonic Pricing Method to Value Rice Genetic Resources in India", in R. Evanson, D. Golan and V. Santaniello (Eds.) (1988), *Agricultural Values of Plant Genetic Resources*, CAB International, Oxford.

Grey, L.C. (1914), "Rent Under the Assumption of Exhaustibility", *Quarterly Journal of Economics*, Vol. 28, No. 4, pp. 466-489.

Hadker, Nandini; Sudhir Sharma, Ashish David and T.R. Muraleedharan (1997), "Willingness to Pay for Borivli National Park: Evidence from a Contingent Valuation Study", *Ecological Economics*, Vol. 21, No. 2, pp. 105-122.

Hanemann, M. (1991), "Willingness to Pay and Willingness to Accept: How Much Can They Differ?", *American Economic Review*, Vol. 81, pp. 635-647.

Hanley, N.; J. Shogren and B. White (1997), *Environmental Economics: Theory and Practice*, McMillan Press, London.

Haripriya, G.S. (1999), "Carbon Stock and Its Value for India", Paper presented in the First Conference of Indian Society for Ecological Economics, Bangalore.

Hartwick, J.M. (1990), "Natural Resources, National Income Accounting and Economic Depreciation", *Journal of Public Economics*, Vol. 43, pp. 291-304.

Hartwick J.M. (1992): "Deforestation and National Accounting", *Environmental and Resource Economics*, Vol. 2, No. 5, pp. 513-522.

Hausman, J. (Ed.) (1993), *Contingent Valuation: A Critical Assessment*, North-Holland Publishing Co., Amsterdam.

Hicks, J.R. (1939), "The Foundation of Welfare Economics", *The Economic Journal*, Vol. 49, pp. 696-712.

Hicks, J.R. (1940), "The Valuation of Social Income", *Economica*, Vol. 8, pp. 105-124.

Hoevenagel, R. (1996), "The Validity of the Contingent Valuation Method: Perfect and Regular Embedding", *Environmental and Resource Economics*, Vol.7, No. 1, pp. 57-78.

Hotelling, H. (1931), "The Economics of Exhaustible Resource", *Journal of Political Economy*, Vol. 39, pp. 137-175.

Howarth, R.B. (1991), "Inter-temporal Equilibria and Exhaustible Resource: An Overlapping Generations Approach", *Ecological Economics*, Vol. 5, No. 3, pp. 237-247.

Hultkrantz, L. (1991), "National Accounting of Timber and Forest Environmental Resource in Sweden", *Environmental and Resource Economics*, Vol.2, pp. 283-305.

International Institute for Environment and Development (IIED) (1994), *Economic Evaluation of Tropical Forest Land Use Options: A Review of Methodology and Applications*, Environment Economic Programme Monograph, London.

James, A.J. and M.N. Murty (1998), "Measuring Non-User Benefits from Cleaning Ganges", Working Paper No. E/202/1999, Institute of Economic Growth, Delhi.

Kadekodi, G.K. (Ed.) (2001), *Environmental Economics in Practice: Case Studies from India*, Monograph under publication,

Kadekodi, G.K. and N.H. Ravindranath (1997), "A Macro-Economic Analysis of Forestry Options on Carbon Sequestration", *Ecological Economics*, Vol. 23, pp. 201-223.

Kadekodi, Gopal, K.; K.S.R. Murthy and K.Kumar (Eds.) (2000), *Water in Kumaon: Ecology, Value and Rights*, Gyanodaya Publications, Nainital.

Kahneman, D. and J. Knetsch, (1992 a), "Valuing Public Goods: The Purchase of Moral Satisfaction", *Journal of Environmental Economics and Management*, Vol. 22, No. 1, pp. 57-70.

Kahneman, D. and J. Knetsch (1992 b), "Contingent Valuation and the Value of Public Goods: Reply", *Journal of Environmental Economics and Management*, Vol. 22, No. 1, pp. 90-94.

Knetsch, J.L. and J.A. Sinden (1984), "Willingness to Pay and Compensation Demanded: Experimental Evidence of an Unexpected Disparity in Measures of Value", *Quarterly Journal of Economics*, Vol. 94, No. 3, pp. 507-521.

Kolstad, C.B. (1999), *Environmental Economics*, Oxford University Press, New York.

Kumar, P. (2000), "Estimation and Economic Valuation of Soil Conservation: A Case Study of Doon Valley", Institute of Economic Growth, Delhi (mimeo.).

Larson, D.M. (1992), "Can Non-Use Value be Measured from Observable Behaviour?", *American Journal of Agricultural Economics*, pp. 1114-1120.

Loomis, J.B. and D.M. Larson (1994), "Total Economic Value of Increasing Gray Whale Populations: Results from a Contingent Valuation Survey of Visitors and Households", *Marine Resource Economics*, Vol. 9, No. 3, pp. 275-286.

Loomis, J.B. and D.S. White (1996), "Economic Benefit of Rare and Endangered Species: Summary and Meta-Analysis", *Ecological Economics*, Vol. 18, pp. 197-206.

Lotka, A. J. (1956), *Elements of Mathematical Biology*, Dover Publications, London.

Magurran, A.E. (1988), *Ecological Diversity and Its Measurement*, Princeton University Press, Princeton, New Jersey.

Maharana, I.; S.C. Rai and E. Sharma (2000), "Environmental Economics of the Khangchendzonga National Park in the Sikkim Himalaya, India", *GeoJournal*, Vol. 50. pp. 329-337.

Maler, K.G. (1991), "National Accounts and Environmental Resources", *Environmental and Resource Economics*, Vol. 1, pp. 1-15.

Manoharan, T.R. (1996), *Economics of Protected Areas: A Case Study of Periyar Tiger Reserve*, Ph.D. Thesis, Forest Research Institute, Dehradun.

Manoharan, T.R. (2000), "Natural Resource Accounting: Economic Valuation of Intangible Benefits of Forests", RISDCP # 04/2000, New Delhi.

Manoharan, T.R. and Sugato Dutt (1999), "Economic Valuation of Eco-Tourism in Kalakadu Mundanthurai Tiger Reserve, Tamil Nadu", Paper presented at the First Biannual Conference of the Indian Society of Ecological Economics held on December 20-22, 1999, Bangalore.

Master, M. (1991), "Assessing Threats and Setting Priorities for Conservation", *Conservation Biology*, Vol. 5, pp. 559-563.

Mitchell, R.C. and R.T. Carson (1989), *Using Survey to Value Public Goods: The Contingent Valuation Method*, Resources for the Future, Washington, D.C.; The Johns Hopkins University Press, Baltimore, U.S.A.

Montgomery, Claire A.; Robert A. Pollak, Kathrya Freemark and Denis White (1999), "Pricing Biodiversity", *Journal of Environmental Economics and Management*, Vol. 38, pp. 1-19.

Munda, G. (1995), *Multicriteria Evaluation in a Fuzzy Environment: Theory and Applications in Ecological Economics*, Physica-Verlag, Heidelberg.

Murty, M.N. and S. Menkhaus (1994), *Economic Aspects of Wildlife Protection in the Developing Countries: A Case Study of Keoladeo National Park, Bharatpur, India*, Institute of Economic Growth, New Delhi (monograph).

Navrud, S. and E.D. Mungatana (1994), "Environmental Valuation in Developing Countries: The Recreational Value of Wildlife Viewing", *Ecological Economics*, Vol. 11, pp. 135-151.

Pandit, M.K. (1997), "Ecological Economics: Towards a Synthesis of Two Disjunct Disciplines", *Current Science*, Vol. 72, No. 2, pp. 119-123.

Parikh, Jyoti (2001), "Valuing the Health Impact of Air Pollution", in G.K. Kadekodi (Ed.) (2001), *Environmental Economics in Practice: Case Studies from India*, Monograph under publication.

Parikh, Jyoti and G.S. Haripriya (1998), "Environmental Accounting in India: Trial Estimates for Forests Resources", IGIDR Working Paper, Indira Gandhi Institute of Development Research, Mumbai.

Parikh, Kirit S. (2001), "Natural Resource Accounting and Monitoring", Indian Society for Ecological Economics (2001), *Ecological Economics for Sustainable Development*, New Delhi, pp. 83-110.

Parikh, K.S. and Utpal Ghosh (1995), "Natural Resource Accounting for Soils: Towards an Empirical Estimate of Costs of Soil Degradation for India", IGIDR Discussion Paper No. 48, Indira Gandhi Institute of Development Research, Mumbai.

Parikh, K.S. and Jyoti Parikh (1997), *Accounting and Valuation of Environment*, Vols. 1 and 2, United Nations, New York.

Pearce, D.W. and D. Moran (1994), *The Economic Value of Biodiversity*, International Union for Conservation of Nature, Earthscan Publications Ltd., London.

Perrings, C. (1995), *Biodiversity Loss: Economic and Ecological Issues*, Cambridge University Press, Cambridge.

Polasky, Stephen and A.R. Solow (1995), "On the Value of a Collection of Species", *Journal of Environmental Economics and Management*, Vol. 29, pp. 298-303.

Polasky, S.; A.R. Solow and J.M. Broadus (1993), "Searching for Uncertain Benefits and the Conservation of Biological Diversity", *Environment Resource Economics*, Vol. 3, pp. 171-181.

Principe, P. (1989), "The Economic Value of Biodiversity Among Medicinal Plants", Organisation of Economic Co-operation and Development, Paris.

Rangarajan, I.N. (1987), *The Arthashastra*, Penguin Books, New Delhi.

Repetto, R.; W. Magrath *et al.* (1989), *Wasting Assets: Natural Resources in the National Income Accounts*, World Resources Institute, New York.

Reyer, G.; P.V. Beukering, M. Verma, P.P. Yadav and P. Pandey (1999), "Integrated Modeling of Solid Waste in India", CREED Working paper No. 26, International Institute for Environment and Development, London.

Ricardo, David (1971 print), *Principles of Political Economy and Taxation*, Penguin Press, London.
Sagoff, M. (1994), "Should Preferences Count", *Land Economics*, Vol. 70, No. 2, pp. 127-144.
Samuelson, O. (1954), "Evaluation of Real National Income", *Oxford Economic Papers*, Vol. 2, pp. 1-29.
Samuelson, P.A. (1948), "Consumption Theory in Terms of Revealed Preference", *Economica*, pp. 243-253.
Samuelson, P.A. (1963), *Foundation of Economic Analysis*, Cambridge University Press, Harvard.
Sankar, U. (2001), "Pollution Control in Tanneries", in G.K. Kadekodi (Ed.) (2001), *Environmental Economics in Practice: Case Studies from India*, Monograph under publication.
Sen, A.K. (1970), "Interpersonal Aggregation and Partial Comparability", *Econometrica*, Vol. 38, pp. 293-409.
Shaffer, M.I. (1983), "Minimal Population Sizes for Species Conservation", *Bioscience*, Vol. 31, pp.131-134.
Shaffer, M.L, and F.B. Samson (1985), "Population Size and Extinction: A Note on Determining Critical Population Sizes", *The American Naturalist*, Vol. 125, No. 1, pp. 144-152.
Shechter, Mordechai (1995), "Valuing the Environment", in H. Folmer, L.H. Gabel and J.B. Opschoor (Eds.) (1995), *Principles of Environmental and Resource Economics*, Edward Elgar Publications, Brookfield, U.K.
Shogren, J.; S. Shin, D. Hayes and J. Kliebenstein (1994), "Resolving Differences in Willingness to Pay and Willingness to Accept", *American Economic Review*, Vol. 84, pp. 255-270.
Singh, T.P. and Ravi Hegde (2001), "Stakeholder Analysis in Joint Forest Management in India: A Case Study of Haryana Shivaliks", in G.K. Kadekodi (Ed.) (2001), *Environmental Economics in Practice: Case Studies from India*, Monograph under publication.
Solow, A. and S. Polasky (1994), "Measuring Biological Diversity", *Environment and Ecological Statistics*, Vol. 1, No. 2, pp. 95-107.
Swanson, T.M. (1994), "The Economics of Extinction Revisited and Revised: A Generalised Framework for the Analysis of the Problems of Endangered Species and Biodiversity Loss", *Oxford Economic Papers*, Vol. 46, pp. 800-821.
Swanson, T.M. and E.B. Barbier (Eds.) (1992), *Economics for the Wilds: Wildlife, Wildlands, Diversity and Development*, Earthscan Publications Ltd., London.
Tobias, D. and Mendelsohn, R. (1991), "Valuing Ecotourism in a Tropical Rain-Forest Reserve", *Ambio*, Vol. 20, No. 2, pp. 91-93.
Turner, R.K. (1993), *Sustainable Environmental Economics and Management: Principles and Practice*, Belhaven Press, New York.
United Nations (1993), "Integrated Environmental and Economic Accounting", in *Studies in Methods*, Series, F. No. 61, Department of Economic and Social Information and Policy Analysis, New York.
United Nations Environment Programme (UNEP) (1993), *Environmental Accounting: A Review of the Current Debate*, Environment Economics Series Paper No. 8, New York.
Thematic Working Group Report for National Biodiversity Action and Strategy Plan (TWGEVA) (2001), Ministry of Environment and Forests, Government of India, New Delhi (Monograph).
Verma, Madhu (2000), *Economic Valuation of Bhoj Wetlands for Sustainable Use*, Monograph Report submitted to Environmental Economics Research Committee for Indira Gandhi Institute for Development Research, Mumbai.
Viscusi, W.K. (1993), "The Value of Risks to Life and Health", *Journal of Economic Literature*, Vol. 31, No. 4, pp. 1912-1946.
Whitehead, J.C. (1993), "Total Economic Values for Coastal and Marine Wildlife: Specification, Validity and Valuation Issues", *Marine Resource Economics*, Vol. 8, pp. 119-132.
Wilson, E.O. (Ed.) (1988), *Biodiversity*, National Academy Press, Washington, D.C., U.S.A.
Wilson, E.O. (1992), *The Diversity of Life*, Norton, New York.