

SPECIAL ISSUE: The Dynamics and Value of Ecosystem Services: Integrating  
Economic and Ecological Perspectives

## Accounting for the value of ecosystem services

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### Abstract

A 'value of ecosystem services' (VES) may be calculated by multiplying a set of ecosystem services by a set of corresponding shadow prices. This paper examines the role of the VES concept in measuring trends in human well-being. Under conventional arguments from applied welfare economics, standard measures of market consumption may be extended to include the value of direct environmental services, which affect welfare in ways that are not mediated by the consumption of purchased goods. The VES concept does not capture values such as ecological sustainability and distributional fairness that are not reducible to individual welfare. And its operationalization is constrained by the well-known limitations of nonmarket valuation methods. Nonetheless, attempts to calculate the value of environmental services can provide insights into the tradeoffs between market activity and environmental quality that are implicit in the process of economic growth. Such efforts can promote informed debate concerning the achievement of sustainable development. © 2002 Elsevier Science B.V. All rights reserved.

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### 1. Introduction

Efforts to assess the monetary value of ecosystem services play multiple roles in managing the links between human and natural systems. At the micro level, valuation studies reveal information on both the structure and functioning of ecosystems and the varied and complex roles of ecosystems in supporting human welfare. Estimates of

marginal benefits can be used as signals to guide the human use of ecosystems, providing information on the relative scarcity and qualitative condition of the natural environment. Valuation is particularly useful in settings where institutional arrangements (such as markets and common property regimes) are not functioning well to reflect the social costs of environmental degradation. Decisions about conservation or restoration actions can lead to the misuse of resources when not guided by some concept of value.

At the macro level, ecosystem valuation can contribute to the construction of indicators of human welfare and sustainability (Daly and

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Cobb, 1989). The processes of production and consumption not only derive inputs from natural systems, but also alter those systems through land-use change and the discharge of waste. Keeping track of how the transformation of ecosystems affects human welfare in both the short and long run is an important—and prudent—accounting activity.

To be sure, ecosystem valuation raises important issues of data and methodology, and by no means captures the full range of normative and practical considerations that surround ecological resource management (van der Straaten, 2000). Heal (2000) for example, argues that “the emphasis on valuing ecosystems and their services is probably misplaced,” while Sagoff (1988) claims that environmental systems are connected to core social values that cannot—or should not—be reduced to monetary terms. These criticisms are addressed in detail by the papers included in this volume. Wilson and Howarth (2002) for example, argue that ecological resource management involves questions of equity that are poorly addressed through the standard methods of environmental valuation.

Despite these caveats, the present paper develops the case that economic valuation can contribute positively to the formulation and evaluation of environmental policies. Environmental systems provide material and experiential benefits that contribute directly to human well-being, and it is meaningful and important to quantify these benefits in understandable terms (Pearce, 1993). In addition, case studies suggest that social willingness to pay for ecological conservation often dwarfs the associated costs. A contingent valuation study by Hagen et al. (1992), for example, found that a U.S. Forest Service plan to conserve spotted owl habitat in California, Oregon, and Washington would provide annual benefits of \$7.5–55.3 billion. These benefits compare with annual costs of \$1.5 billion through reductions in timber extraction and regional economic activity. Analyses of this type confirm the importance that the public attaches to ecological systems.

As a specific area of practice, ecosystem valuation has recently taken a visible step forward

through the work of Daily (1997) and Costanza et al. (1997). While Daily’s edited volume provides a diverse set of perspectives on the links between specific ecological services and economic values, Costanza et al. attempt the more ambitious task of estimating the aggregate economic value of ecosystem services, accounting for all of the benefits that human beings derive from natural systems. Although constrained by the limited extent of the existing empirical literature and the need for further research on economy–environment interactions, Costanza et al. staked the controversial claim that ecosystem services provide global benefits of \$33 trillion per year, a figure that exceeds the gross world product by 83%. Methodologically, this estimate was obtained by multiplying the level of each environmental service by an accompanying shadow price that represents the marginal value of the services in question. In this way, Costanza et al. estimated what might be termed the ‘Value of Ecosystem Services’ (VES)—the expenditure that would be required to purchase available ecosystem services at their shadow prices. This technique is analogous to the concept of gross domestic product (GDP), which measures the total value of market goods and services evaluated at market prices.

The Costanza et al. paper is both widely cited and widely criticized. Pearce (1995) for example, argues that environmental valuation should be linked to the concepts of willingness to pay for nonmarket benefits or willingness to accept compensation for nonmarket costs. Pearce notes that the VES estimates reported by Costanza et al. must overstate willingness to pay for ecosystem services since the numbers in question exceed total world income, and people cannot pay more than this income without depleting stocks of capital assets. In a similar vein, Pearce argues that Costanza et al. understate the payment required to compensate people for the loss of all ecosystem services, which, of course, would imply the extinction of the human species—a cost that a rational person would presumably regard as undefinably large. Since the use of cost-benefit analysis in applied microeconomics depends critically on the concepts of willingness to pay and willingness to

accept compensation for environmental and economic changes, Pearce argues that the VES concept is of little relevance in the evaluation of particular conservation programs and management strategies.

The present paper argues that there are important reasons to believe that suitably specified VES measures are conceptually sound in the evaluation of macro level ecological trends. As is well known, conventional macroeconomic indicators ignore both the contributions of nonmarket environmental services to human well-being and the costs that the depletion of natural capital imposes on future generations. The paper argues that the VES approach, if implemented in a consistent manner, offers a logical extension of conventional methods of national accounting. While the specific data and methods presented by Costanza et al. are provisional and open to criticism, the method itself is worthy of development. These conclusions flow from a simple exposition of the concepts and methods of environmental accounting.

## 2. Macroeconomic valuation of ecosystem services: comparative statics

Heuristic insights into the problem of ecosystem valuation may be gleaned from the simplified model presented in Fig. 1, which depicts the marginal benefits (MB) derived from the provisioning

on an environmental service ( $S$ ). We might interpret  $S$  in terms of flows of an extractive resource such as fish, timber, or agricultural products. Alternatively,  $S$  might reflect the level of amenity services—the quiet of the woods or the existence value of a unique ecosystem or endangered species. In either case, we shall assume that MB is a measure of the net benefits derived from the environment, accounting for the costs of resource harvesting and other activities required to support and experience the service in question.

Under standard microeconomic arguments, the total benefits derived from a given level of services ( $S_0$ ) is measured by the area under the marginal benefits curve:

$$B(S_0) = \int_0^{S_0} MB(S) dS \quad (1)$$

At this level of supply, the shadow price  $P_0$  represents the marginal contribution that ecological resources make to the satisfaction of human preferences expressed in monetary units. This shadow price might be estimated using the familiar tools of nonmarket valuation—the travel cost method, hedonic pricing, contingent valuation, etc. (Pearce, 1993). Under this notation, we define the product  $P_0 S_0$  as the VES rendered by this good.

We begin our analysis by noting that the benefits of a small change in the service level  $\Delta S$  may be written:

$$\Delta B = \frac{dB}{dS} \Delta S = P_0 \Delta S \quad (2)$$

The change in VES associated with this same change in services is also  $P_0 \Delta S$ , the product of the shadow price and the change in the service level. This conclusion is based on the assumption that the change in services is small enough to leave the shadow price unchanged. The inference is that for marginal changes in environmental services, VES provides a correct basis for measuring changes in total environmental benefits. Accordingly, VES is a conceptually appropriate basis for measuring welfare changes. While this observation is of some theoretical interest, its main importance is practical. In a world of incomplete data and scientific knowledge, it may be quite difficult to estimate

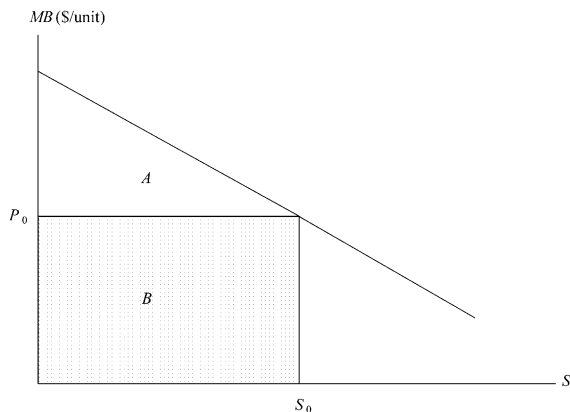


Fig. 1. A heuristic model of ecosystem valuation.

society's full willingness to pay for environmental services as captured by the area  $A + B$  in Fig. 1. Point estimates of shadow prices, however, are generally sufficient to evaluate the welfare effects associated with small changes in environmental services. They do not require information on the full structure of the benefits function.

More formally, consider a static economy in which a typical person attains the utility level  $U(C, S)$  from the consumption of market commodities ( $C$ ) and from environmental services ( $S$ ) that have a direct bearing on individual welfare (i.e. that are not mediated by the production and consumption of market commodities). In this context,  $S$  would include services such as the enjoyment of clean air and water, pleasant views, and recreational opportunities. It would not, however, include indirect services such as the provision of timber and raw materials or the benefits of water quality to commercial fisheries, each of which enters the utility function through the consumption of produced goods ( $C$ ).

Applied economists often measure welfare changes in terms of the prevailing levels of production and consumption. An increase in  $C$  might therefore be interpreted as an improvement in 'social welfare' given a constant state of environmental quality. Note, however, that a shift from the point  $(C, S)$  to the alternative  $(C + \Delta C, S + \Delta S)$  yields the change in utility:

$$\Delta U = \frac{\partial U}{\partial C} \Delta C + \frac{\partial U}{\partial S} \Delta S \quad (3)$$

An increase in consumption ( $\Delta C$ ) may or may not lead to an increase in welfare depending on the change in ecosystem services ( $\Delta S$ ). Now suppose that we define:

$$P = \frac{\partial U / \partial S}{\partial U / \partial C} \quad (4)$$

as the shadow price of environmental services, or the marginal rate of substitution between consumption and environmental quality. Under standard economic arguments,  $P$  measures an individual's marginal willingness to pay for an increase in ecosystem services. Similarly, we define:

$$C^* = C + PS \quad (5)$$

as a measure of 'full consumption,' including the value of both market goods and nonmarket environmental services. From these definitions, it follows that the change in full consumption caused by a small shift in consumption and environmental services may be used to gauge changes in the perceived welfare of a representative member of society. To see this, note that the definitions described above imply that:

$$\Delta U = \frac{\partial U}{\partial C} (\Delta C + P \Delta S) = \frac{\partial U}{\partial C} \Delta C^* \quad (6)$$

Since the marginal utility of consumption is presumably positive, it follows that an increase (or decrease) in full consumption generates proportional changes in subjective well-being. This highlights the need to evaluate  $P \Delta S$  when considering tradeoffs between consumption and environmental services. For example, we must compare the value of timber harvested from a forest with the loss of recreational value if timber and recreation are in conflict.

The points to note here are that: (1) standard measures of market consumption are based on an accounting framework in which the consumption of each good is multiplied by the good's price; and (2) the notion of full consumption extends this framework to include the value of ecosystem services that directly affect people's perceived satisfaction. Thus VES as we defined it above is an appropriate indicator of the welfare provided directly by environmental systems. The accounting problem is to extend consumption indicators to include the contributions of direct environmental services that are not explicitly linked to market transactions.

It is important to recognize the distinction between direct and indirect environmental services in this framework. Since consumption itself reflects the contribution that ecosystems provide to the production of market goods, only the value of direct environmental services should be added to consumption in evaluating welfare changes. Of course, the distinction between direct and indirect environmental services is sometimes subtle in practical applications. Since a single service may

provide both direct and indirect benefits—clean water benefits both swimmers and commercial fishermen—careful attention is required to the nature and incidence of environmental benefits in constructing full consumption measures.

The full consumption concept does not entail that VES represents what might be termed the ‘Total Value of Nature.’ First, the full value of nature, understood in terms of willingness to pay or accept compensation for changes in environmental services, is reflected by the sum of areas *A* and *B* in Fig. 1, not just area *B*. Second, in addition to providing services that directly enter into utility functions, nature provides services that contribute indirectly to welfare by enhancing market-based production and consumption activities. We suggest that calculating the VES of direct environmental services can meaningfully augment traditional welfare accounting. The shadow value of indirect services could be used to construct a similar measure reflecting contributions to market activity.

The analysis presented above focuses on a simple static economy. It is readily apparent, however, that the notion of full consumption may be used to evaluate welfare changes in a dynamic, intertemporal economy subject to certain caveats. First, the structure of preferences—i.e. the roles of consumption and the environment in promoting human welfare—must be invariant over time. While this assumption may seem uncontroversial, it in fact opens up important questions for social science research. Scitovsky (1992) for example, suggests that process such as habit formation and relative consumption effects imply that preferences evolve and change over time. Norton et al. (1998) and Brekke and Howarth (2000) explore this issue in some detail as it relates to environmental and ecological economics.

Second, it should be borne in mind that the notion of a ‘representative’ person can obscure inequalities in society. According to Frank (2000) more than 70% of the increase in the US standard of living that has occurred since 1973 has been captured by the top 1% of the income distribution, while low-income households have lost ground. To base welfare evaluations on changes in average consumption is thus problematic. Ide-

ally, analysts would construct a suite of indicators that focused on the situations of various economic and social groups. The methods described in this paper could, without difficulty, be extended in this direction.

Third, questions of irreversibility and uncertainty raise key issues for environmental valuation. As is well known, scientific uncertainty may obscure the biophysical processes through which a given ecosystem confers benefits on human beings. If, for example, scientists overestimated the ability of aquatic ecosystems to assimilate excess loads of nutrients and acidifying substances, then ecological economists would, of course, underestimate the value of waste sink services—the ability to sustain healthy fish populations, water quality, and recreational opportunities—provided by lakes and rivers. Given the limits of scientific understanding and the potential for catastrophic costs as the result of ecological degradation, a range of authors have embraced the concepts of resilience (Barbier et al., 1994) and strong sustainability (Howarth, 1997) as guides to resource management. These concepts involve maintaining the structure and functioning of ecosystems to provide sustained benefits for future generations, even when such benefits cannot be quantified in economic terms. Of course, adherence to these principles need not imply the rejection of environmental valuation (in general) and the VES concept (in particular). As Norgaard (1989) notes, methodological pluralism is an important guidepost in ecological economics.

Finally, we have discussed the importance of adding direct environmental services to standard measures of consumption in gauging welfare changes. A wealth of evidence, however, suggests that other nonmarket goods—such as leisure, household production, and the quality or ‘thickness’ of social relationships—have an important bearing on human welfare. As Daly and Cobb (1989) point out, the material economic growth of the last three decades has been matched by substantial reductions in the enjoyment of these goods. There are strong reasons to include these effects in measures of full consumption.

### 3. Dynamic measures of welfare and sustainability

The question of sustainability has generated a substantial literature in ecological economics since this concept rose to prominence in the late 1980s. According to Pezzey's (1989) influential definition, an economy is 'sustainable' if the short-term actions of producers and consumers do not diminish the maximum level of human welfare that can be maintained into the indefinite future. While the Brundtland Commission's definition of 'sustainable development' entails a more structured approach in which questions of distributional equity (addressing the basic needs of the world's poorest persons) and ecological sustainability (protecting the environmental services on which all life depends) are identified as core social objectives (WCED, 1987), Pezzey's notion of so-called 'weak sustainability' (maintaining human welfare) remains plausible and important (see Howarth, 1997).

The use of full consumption measures to evaluate welfare changes was described in the preceding section. Given comprehensive data and careful attention to all relevant factors, analysts could, in principle, construct precise indicators of human well-being for use in both historical studies and forward-looking models of economic trends. A 'sustainable' economy would then exhibit constant or increasing levels of full consumption, measured in per capita terms, over its entire time horizon. A range of authors, however, suggest a stronger interpretation. Atkinson et al. (1997), for example, argue that a direct indicator of sustainability may be obtained by adjusting standard measures of economic output—the sum of both consumption and net capital investment—to include the value of environmental services and the depletion of natural capital. If the resulting measure is constant or increasing from one year to the next, then (according to Atkinson et al.) the economy is sustainable in Pezzey's sense.

Atkinson et al.'s approach to the construction of sustainability indicators draws on the work of Hartwick (1977) and Solow (1986), who examined the conditions under which a constant level of well-being could be maintained over an infinite time horizon in a class of theoretical models.

Consider the case of an economy in which population and technology are constant, there is no international trade, and resources are allocated in a fully efficient manner by private markets and public policies. Let  $\Delta K$  measure investments in manufactured capital net of depreciation, while  $\Delta R$  is the change in stocks of natural capital such as fisheries, forests, wetlands, biodiversity, and mineral deposits. Finally, define  $Q$  as the shadow price of natural capital, or the discounted value of the net benefit stream obtained by a marginal increase in resource stocks, with the discount rate set equal to the marginal productivity of capital investment (Hartwick and Olewiler, 1998). Under these assumptions, a representative person will achieve a constant level of utility if the rate of manufactured capital investment is set equal to the monetary value of natural capital depletion so that:

$$\Delta K = -Q\Delta R \quad (7)$$

at every point in time. In this case, natural capital would include all forms of environmental resources, regardless of whether their services were direct or indirect.

The theoretical condition embodied in this equation has fostered enthusiasm that the development of appropriate accounting procedures might effectively resolve the problem of monitoring progress towards achieving sustainability. Repetto et al. (1988) for example, examined trends in capital investment and natural resource depletion for the Indonesian economy between 1971 and 1984. While investments in manufactured capital averaged 2051 billion 1973 Rupiah per year over this period, the depletion of petroleum, timber, and soil resources led to unaccounted losses over half as large. In this sense, conventional measures of capital accumulation substantially overstate the true increase in national wealth that occurred in this economy.

The concepts and methods discussed above are brought together in the construction of adjusted measures of aggregate economic activity. To see this, note that the conventional measure of net domestic product (or gross domestic product less depreciation of manufactured capital) is:

$$NDP = C + \Delta K \quad (8)$$

If consumption is adjusted to incorporate the value of direct environmental services, and if net investment is adjusted to account for natural resource depletion, then one may define:

$$NDP^* = (C + PS) + (\Delta K + Q\Delta R) \quad (9)$$

as a measure of full net domestic product. Although this indicator is sometimes interpreted as the maximum level of full consumption that can be sustained into the long-term future, this interpretation holds only for economies in which population, technology, and terms of trade are constant, and where net investment exceeds the monetary value of resource depletion at all points in time (see Brekke, 1997). As Asheim (1994) shows in rigorous mathematical terms, it is impossible in principle to gauge the sustainability of an economic system based solely on current patterns of consumption and investment. Instead, analysts must model the economy's development into the long-term future, explicitly examining the impacts of present choices on the welfare of future generations.

Adjustments to NDP for the loss of natural capital must reflect changes in both the physical quantity and quality of resource stocks. Since 'natural capital' is defined in terms of the ability of ecosystems to provide sustained flows of services, the qualitative impairment of ecosystems constitutes the loss of a valuable resource. For example, siltation and nutrient enrichment may lead to the loss of biodiversity in a coastal wetland, even if the gross area of the wetland remains unchanged. Some subtlety is often required in the construction of measures to evaluate such effects. The key point is that the variable  $R$  as defined in this discussion represents a comprehensive index of the state of the environment.

#### 4. Summary and conclusions

Costanza et al. (1997) estimate that the Earth's ecosystems provide services worth some \$33 trillion per year to human beings. In this calculation, a set of specified services is multiplied by a set of

corresponding shadow prices to gauge the total VES. This paper examines the theoretical foundations of ecosystem valuation, finding that the VES concept is conceptually sound from the perspective of applied welfare economics. VES is structurally similar to the notion of gross domestic product, which measures the total value of market goods and services evaluated at market prices.

In constructing monetary measures of economic welfare, it is theoretically necessary to incorporate the value of direct environmental services—those that bear directly on people's perceived well-being that are not connected to market transactions. The list of such services is decidedly broad, and would include the value of environmental amenities, the health services provided by clean air and clean water, and the existence value of unique species and ecosystems. Costanza et al.'s VES measure is more all encompassing, including both direct environmental services and the indirect benefits that ecosystems provide through the production of market goods. These indirect benefits are reflected in standard measures of market consumption.

In the years since the concept of sustainable development was popularized by the Brundtland Commission (WCED, 1987), much enthusiasm has focused on the notion that standard measures of economic output—including the value of both consumption and net investment—might be extended to account for the value of ecosystem services and the loss of natural capital. Atkinson et al. (1997), for example, argue that the notion of full net domestic product ( $NDP^*$ ) provides an index of the maximum level of economic welfare that can be sustained over time. This interpretation, however, rests on restrictive assumptions: Population, technology, preferences, and terms of trade must all remain constant, while the economy must be steered by a set of institutions that ensures that resources are allocated in a fully efficient manner. Where these assumptions are violated—as they typically are in real-world economies—full NDP loses its force as a sustainability indicator. Rather than relying on simple accounting formulae, analysts must build forecasting models that predict future environmental and economic trends, explicitly analyzing the

tradeoffs between short-term decisions and long-term welfare. The notion of full consumption ( $C^*$ ), which accounts for the value of both market goods and nonmarket environmental services, offers a useful means of evaluating such tradeoffs.

In concluding this paper, it is useful to note some important caveats. First, welfare measures that emphasize a 'typical' or 'representative' member of society can provide incomplete and even misleading insights on the performance of economies characterized by high (and changing) degrees of inequality. Ideally, analysts would take a more disaggregated approach that considered the life circumstances of a range of social groups. Welfare indicators should account for changes in leisure, household production, and the quality of social interactions. Both incomes and access to environmental services should be considered in characterizing inequalities. In this sense, the interests of ecological economics might be more closely linked to those of political ecology (see Daly and Cobb, 1989).

Second, efforts to place shadow prices on certain types of ecosystem services can run into substantial conceptual and empirical difficulties (Heal, 2000). Some services, for example, may lack substitutes or be seen as morally incommensurable with market commodities (Sagoff, 1988). Moral values, although of key importance to environmental management, cannot be reduced to the monetary calculus of cost-benefit analysis and VES measurement. In addition, the services themselves may be connected to high degrees of scientific uncertainty. For example, attempts to value the flood protection service provided by barrier islands must be based on complex hydrological models of coastal ecosystems. Uncertainties or errors in the underlying science can generate imprecision or bias in valuation figures.

While the concept of sustainable development entails a concern for maintaining human welfare (Pezzey, 1989), important arguments support the notion that the satisfaction of basic needs and the conservation of unique environmental systems are morally, or instrumentally, essential to ensure the broad aims of the Brundtland Commission (Howarth, 1997). While ecosystem valuation can improve the basis of welfare measurement, it

sheds less light on the questions of social fairness and ecological sustainability, the latter being more closely linked to physical measures of environmental conditions. As Norgaard (1989) notes, achieving sustainable development will require a pluralist approach that involves (but does not reduce to) questions of environmental valuation. In this perspective, valuation, ecological assessment, and equity analysis are properly viewed as complements, not substitutes.

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## References

- Asheim, G.B., 1994. Net national product as an indicator of sustainability. *Scandinavian Journal of Economics* 96, 257–265.
- Atkinson, G., Dubourg, R., Hamilton, K., Munasinghe, M., Pearce, D., Young, C., 1997. *Measuring Sustainable Development: Macroeconomics and the Environment*. Edward Elgar, London.
- Barbier, E.B., Burgess, J.C., Folke, C., 1994. *Paradise lost? The Ecological Economics of Biodiversity*. Earthscan, London.
- Brekke, K.A., 1997. *Economic Growth and the Environment*. Edward Elgar, London.
- Brekke, K.A., Howarth, R.B., 2000. The social contingency of wants: implications for growth and the environment. *Land Economics* 76, 493–503.
- Costanza, R., d'Arge, R., deGroot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. *Nature* 387, 253–260.
- Daily, G. (Ed.), 1997. *Nature's Services*. Island Press, Washington.
- Daly, H.E., Cobb, J.B., 1989. *For the Common Good*. Beacon Press, Boston.
- Frank, R.H., 2000. Market failures. In: Cohen, J., Rogers, J. (Eds.), *Do Americans Shop Too Much?* Beacon Press, Boston.



- Hagen, D.A., Vincent, J.W., Welle, P.G., 1992. Benefits of preserving old-growth forests and the spotted owl. *Contemporary Economic Policy* 10, 13–25.
- Hartwick, J.M., 1977. Intergenerational equity and the investing of rents from exhaustible resources. *American Economic Review* 67, 972–974.
- Hartwick, J.M., Olewiler, N.D., 1998. *The Economics of Natural Resource Use*. Addison-Wesley, Reading, MA.
- Heal, G., 2000. Valuing ecosystem services. *Ecosystems* 3, 24–30.
- Howarth, R.B., 1997. Sustainability as opportunity. *Land Economics* 73, 569–579.
- Norgaard, R.B., 1989. The case for methodological pluralism. *Ecological Economics* 1, 37–57.
- Norton, B., Costanza, R., Bishop, R.C., 1998. The evolution of preferences: why ‘sovereign’ preferences may not lead to sustainable policies and what to do about it. *Ecological Economics* 24, 193–211.
- Pearce, D.W., 1993. *Economic Values and the Natural World*. MIT Press, Cambridge, MA.
- Pearce, D.W., 1995. Auditing the earth. *Environment* 40 (2), 23–28.
- Pezzey, J., 1989. Economic analysis of sustainable growth and sustainable development. Environment Department Working Paper No. 15, The World Bank.
- Repetto, R., Magrath, W., Wells, M., Beer, C., Rossini, F., 1988. *Wasting Assets: Natural Resources in the National Accounts*. World Resources Institute, Washington.
- van der Straaten, J., 2000. The economic value of nature. In: Briassoulis, H., van der Straaten, J. (Eds.), *Tourism and the Environment*. Kluwer, Dordrecht, pp. 123–132.
- Solow, R.M., 1986. On the intergenerational allocation of natural resources. *Scandinavian Journal of Economics* 88, 141–149.
- van der Straaten, J., 2000. The economic value of nature. In: Briassoulis, H., van der Straaten, J. (Eds.), *Tourism and the Environment*. Kluwer, Dordrecht, pp. 123–132.
- Wilson, M.A., Howarth, R.B., 2002. Distributional fairness and ecosystem service valuation. *Ecological Economics* (this issue).
- World Commission on Environment and Development (WCED), 1987. *Our Common Future*. Oxford University Press, New York.