Environmental Valuation in Europe

Policy Research Brief

Number 3

Natural Capital

by Martin O'Connor

Series Editors: Clive L. Spash & Claudia Carter

Concerted Action funded by the European Commission DG-XII and co-ordinated by Cambridge Research for the Environment (CRE)

CONTENTS page

This policy research brief draws on presentations and contributions made at the third EVE workshop entitled 'The Evaluation of Natural Capital' held in Paris, France, 24–26 March 1999, organised by Martin O'Connor and Jessy Tsang of the Centre d'Economie et d'Ethique pour l'Environnement et le Développement (C3ED), Université de Versailles Saint-Quentin-en-Yvelines, France, in cooperation with IRD, Paris.

This policy research brief was written by Martin O'Connor and produced by the series editors Clive L. Spash and Claudia Carter.

Front cover: Attempts to maintain 'natural capital' are illustrated by the designation of 'wild' areas as National Parks. Zion Canyon National Park, Utah. Photo by C. Carter.

ISBN 186190 083X

Printed on paper produced from 100% recycled fibres

Overview

This policy research brief presents key concepts and examples of environmental valuation challenges, organised around 'natural capital'. The concept of natural capital involves the extension of well-established economic and accountancy notions of a firm's assets as the stocks and equipment from which income is derived:

> Natural capital is the stock that yields the flow of natural resource; the population of fish in the ocean that regenerates the flow of caught fish that go to market, the standing forest that regenerates the flow of cut timber; the petroleum deposits in the ground whose liquidation yields the flow of pumped crude oil. (Daly 1994, p. 30)

Attributes of natural capital and its distinction from man-made capital is elaborated in the section on Natural Capital and Sustainability (pp. 4–5) along with resource scarcity, vulnerability and depletion which are all key concerns in defining sustainable paths of human existence.

Because concepts of wealth and progress have tended to centre around monetary measures it is tempting to expand this to natural capital. The section on the Monetisation Frontier (pp. 6–10) discusses a methodological concept which identifies the boundary dividing environmental information in monetary terms from information in a variety of non-monetised forms. Those who prefer monetisation, favour the use of inventories of environmental functions and changes in the services capacity of the environment (usually as part of a comprehensive environmental cost-benefit analysis). Those on the other side of the frontier require multi-dimensional information sets on the state of the environment and on the various pressures imposed by human societies on their environments. This information can be a basis for defining sustainability standards, critical thresholds and performance goals as elements in multi-criteria evaluation of development prospects (see also Policy Research Brief 2).

Aggregate and single measures have been used to define stocks and the quality of goods and services obtainable in non-monetary terms, focusing on the maintenance of *environmental functions*. The section entitled Environmental Systems Dynamics and Critical Natural Capital (pp. 11–16) discusses such frameworks for the evaluation of the economic and social significance of natural capital.

The fourth section, From Information to Deliberation (pp. 17–19) focuses on the key role of environmental information in supporting decision-making and conflict resolution. This brief concludes with a section of Key Points (p. 20) of the recursive relation between learning about natural systems and their potentials and deliberation within society about the justifications for and against different policies.

Natural Capital and Sustainability

There is no satisfactory indicator for the total quantity or stock of natural capital.

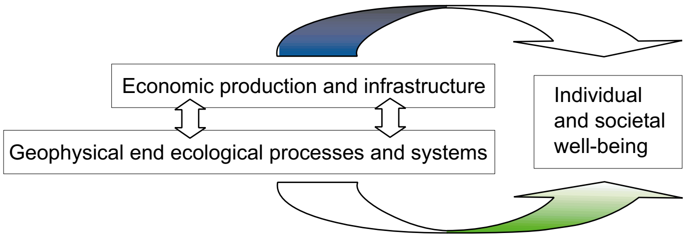
An economic resource or service is defined as scarce if its use significantly reduces other opportunities (an 'opportunity cost') for members of society elsewhere or in the future. Environmental services such as clean air and water were once perceived as abundant and treated as free goods but are now increasingly acknowledged as being depletable and destructible. Imprudent activities by society can intensify resource constraints. For any vision of 'development', information on exploitation opportunities and the trade-offs imposed by scarcity and renewal rates becomes crucial.

Natural capital is a hybrid concept. On the one hand it is a concept borrowed from economics; on the other it points to the importance of environmental quality, resilience and integrity as pre-conditions for human well-being and long-term sustainable economic activity as illustrated in Figure 1. Natural capital differs from man-made (manufactured) capital in several ways:

- First, natural capital is essentially an endowment of nature. It cannot be reproduced by human societies, only modified. Examples of endowment such as mineral deposits or genetic components are the given 'base' and are substantially irreplaceable.
- Second, environmental resources are not just physical stocks but dynamic systems that serve a multiplicity of functions, including life-support for human and non-human communities. Manufactured capital can only substitute some natural capital as a basis for human welfare – usually at high costs and for limited spheres.
- Third, changes in the natural environment caused by human activities are often irreversible. The irreversibility of energy has been emphasised, on thermodymanic grounds, by pioneering ecological economists such as Georgescu-Roegen, Passet, Boulding, Daly, Martinez-Alier, Faber and Norgaard. Biologist Rachel Carson in *Silent Spring* (1960) highlighted the irreversibility of imminent disappearance of species loss due to indiscriminate pesticide use.

Emphasis is placed on ecosystems (and the biosphere more generally) as dynamic processes upon which human economic activity and well-being depends. Natural capital systems are fragile. Once degraded, they may never recover, with consequences for economic viability and human health. Once this systems perspective is established, information collection concerns the functioning of the environmental systems and the services or functions provided for economic activity and human well-being by the natural systems.

Figure 1. Natural capital and human well-being



Natural capital is represented by the lower box, the geophysical and ecological systems. These are the components of our physical and living world that underpin all economic activity and that provide, directly and indirectly, the environment that keeps us alive.

Policies for sustainability require that present generations' economic activity does not prejudice the welfare of future generations by running down irreversibly the stocks of environmental assets. Some economists in this context have proposed a rule of 'non-negative change' to natural capital – that is, maintenance of the stocks of natural resources such as ground and surface water and their quality.

Attempts of defining aggregate measures of capital stock have so far included:

- the physical quantity of natural resource stocks;
- the total value (in economic units) of the natural resource stocks, which would permit physically declining levels of a stock if accompanied by a rising unit value (price);
- the unit value of the resource/service (as measured by a price or shadow price);
- the total value of the resource/service obtained through time from the stock.

Although these measures seem intuitively meaningful, they require a comprehensive procedure for measurement and evaluation which is simply not possible. Major difficulties arise from the large diversity of environmental capitals and translation of benefits – ranging from fundamental life-support functions of the biosphere to ecosystems as reservoirs of cultural, biological and scientific interest – onto a single evaluation scale. The last of the four measures is particularly problematic with insurmountable difficulties of operationalisation. It encapsulates the conventional economist's idea of a sustainable development: ensuring a non-declining benefit stream of environmental services. In standard economic analysis, relative prices are used as an estimator of opportunity costs associated with production or use of different goods and services. But correct monetary valuation of natural capital requires knowing the extent to which different natural stocks are substitutable for each other or by manufactured capital. If physical units are used, a variety of scientifically valid measures can be obtained – such as tonnes of material or joules of available energy. One is then faced with the problem of meaningfulness and policy relevance of aggregate measures for composite stocks. The conclusion is that, in general, there is no fully satisfactory indicator for the total quantity or stock of natural capital.

The Monetisation Frontier

An underlying principle for monetary environmental valuation is that, although we cannot introduce all ecological goods and services into actual markets, it is possible to obtain a monetary estimate of the value of some environmental good or the cost of some environmental harm. Such pricing can be approached in two ways:

- on the supply side through estimates of economic costs – required to obtain an extra environmental benefit, or to repair damage, or to avoid further deterioration;
- on the demand side through estimates of the monetary value of the benefits that are lost or at risk.

Refusal of monetary valuations is not a sign of irrationality or ignorance.

Examples of approaches to environmental valuation from the supply side include restoration and avoidance costs. Restoration costs are paid (potentially or otherwise) by individuals, firms and state institutions in response to environmental pollution, to maintain or restore, for example, rivers and lakes to certain levels of water quality and fishery stock – or to remedy human health problems due to pollutants. Avoidance costs are incurred (or potentially incurred) to avoid environmental damage such as the costs of introducing traffic calming and noise buffer measures in towns, or of reducing atmospheric greenhouse gas emissions, or of improving safety measures against spills of toxic chemicals in storage.

The monetary figures obtained with supply-side approaches relate to expenditures to achieve improvements or stabilisation in environmental quality. Such figures do not necessarily provide an estimate of the monetary value of the benefits gained. For example, the restoration benefits of forest replanting might be much greater than the costs to a landowner, but these benefits may partly accrue to other persons over a long period of time (e.g. future wood harvest, improved groundwater quality).

The demand for environmental benefits refers to how much people are, or would be, willing to pay for specified environmental benefits or to avoid environmental damage. This is usually, but not necessarily, measured in money units. In the example of natural capital that is used as productive inputs, it is possible to specify a 'derived demand' – an amount that a user would be willing to pay as reflected by the revenue stream that is obtainable, such as timber products from a forest. However, for non-commodified environmental services, no such commercial reference point exists and various artifices must be employed (see Policy Research Brief 1 for an overview of commonly used techniques such as Travel Cost Method, Hedonic Pricing and Contingent Valuation Method).

A fundamental question is: 'Why try to put money figures on environmental changes?' The reason often given is that this provides a common and understandable measure through which different objectives can be traded-off. Thus, the loss in relation to one objective can be quantified against the gain in relation to another. Yet, the 'demand' for environmental quality cannot always be satisfactorily expressed as values in monetary terms. Difficulties mainly arise from trying to transpose traditional economic valuation methodologies into domains for which they were not originally devised, namely:

- extension to the non-produced and largely non-commodified natural environment;
- extension temporally to long-term ecological change and sustainability concerns.

Critisism or refusal of monetary valuations is not a sign of irrationality or ignorance on the part of citizens. Rather, it is a coherent and reasonable response, given the inherent properties of environmental problems, notably the irreducible uncertainties, the high decision stakes and long risk/impact time-horizons, ethical convictions and the problems of distributional justice. These issues may be classed together as challenges of complexity (see Box 1).

Environmental decision-making, like all other policy fields, necessarily decides for certain interests over others. Environmental policies typically involve identifying, managing and, partially, resolving ecological (as well as economic) distribution conflicts. These are often particularly difficult because policy involves sharing out 'bads' – e.g. risk distribution and imposed suffering such as health damage – as well as 'goods'. Side effects on health and ecological systems will in many cases only fully emerge over long periods of time and across large distances. The affected parties may be extremely diffuse or hypothetical in character (e.g. future generations and ecosystems that may be affected by climate change or accumulation of carcinogenic contaminants).

Box 1: The Challenges of Complexity

Assessments of natural capital are caught up by three challenges, which overlap and interfere with each other:

- Scientific knowledge advising of irreducible uncertainties and/or irreversibilities associated with courses of action;
- Plurality of value systems, political and moral convictions, and justification criteria within society;
- High decision stakes including economic interests and strategic security concerns for nations or ethnic minorities, and also consequences of environmental change for public health, organism integrity and future economic possibilities.

For more information on these issues, see Policy Research Briefs 2, 4 and 6.

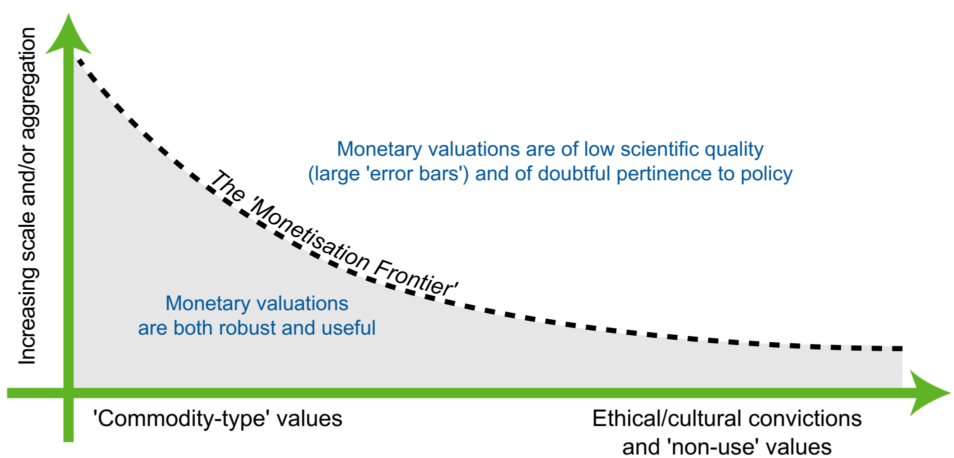
These sorts of questions led, during the EVE Workshop on Natural Capital, to the development of a simple heuristic concept, the **Frontier of Monetisation**. The concept addresses (a) the extent to which monetary valuation can be scientifically meaningful, and (b) the policy relevance of the monetary figures. Two main dimensions are considered. The first concerns matters of scale and aggregation, the second concerns the kinds of value involved. These are portrayed schematically in Figure 2 showing the zone where monetary valuation can be meaningful and policy-relevant.

The 'scale' consideration, along the vertical axis in Figure 2, has direct consequences for procedures of monetary aggregation. Monetary valuation will produce low quality numbers with high uncertainties and low policy relevance where systems complexity is high and relevant time-scales of environmental effects or their economic feedback consequences are long.

The 'value type' consideration, along the horizontal axis, has important consequences for measurability and comparability. Where values are strongly based on ethical or cultural precepts, monetary valuation is less appropriate. For example, peoples whose ecological base of subsistence, such as forest or coastal waters, is destroyed by a development project. The values are not oriented uniquely towards commodity production and consumption but involve notions of self, justice and honour, cultural identity and cosmic harmony. In this case, conflict resolution is not a question of economic optimisation! Most sustainability policy choices include ethical components, e.g. questions of wealth distribution or equity issues relating to future generations. In part they are seen, also, in the debates about the moral acceptability or social justifications for certain policies such as intervening in the genetic integrity of organisms or destroying habitats of endangered species.

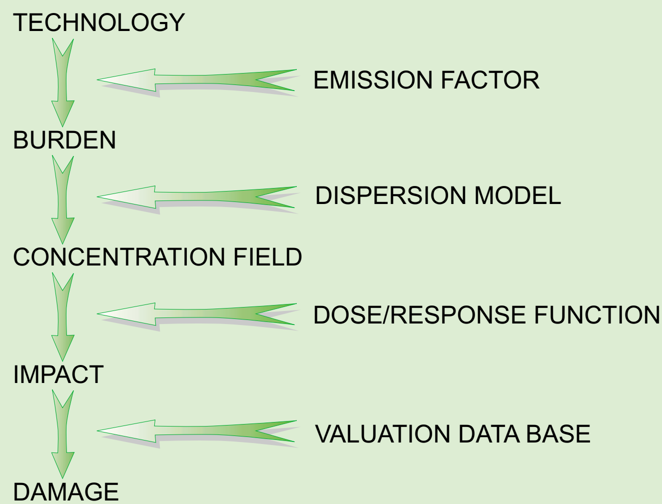
Following are two contrasting examples where the Frontier of Monetisation concept enhances understanding of methodological choices for organising environmental information.

Figure 2. The 'Frontier of Monetisation' (developed by M. O'Connor and A. Steurer)



Box 2: The ExternE Impact Pathway Methodology

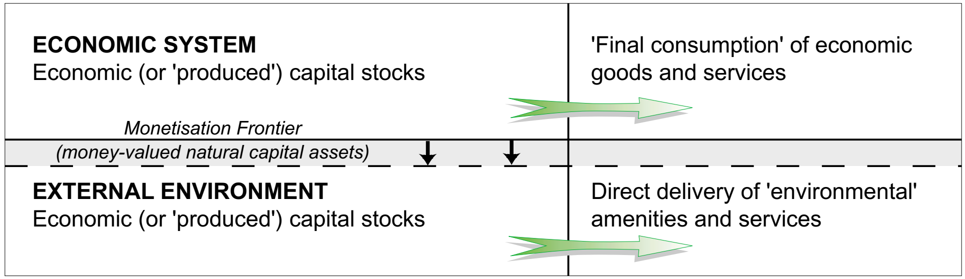
In the Dose-Response step of analysis, data from the physical and biological sciences are used to link a particular sort of pollution at different levels (the dose) with different levels of physical damage to human, animal and plant communities (the environment's response). This approach has the advantage of being a relatively systematic way of identifying changes in the environment caused by economic activities, that is, of estimating what economists call a 'damage function'. However, it is time-consuming and the calculation process is highly site sensitive for two reasons. First, the data and/or model used at each stage may be dependent on the location. Second, the aggregate impact is determined by the geographical distribution of victims or receptor ecosystems. Finally, there is the possibility that important environmental functions beneficial to society go unnoticed and that some significant damage effects may be left out (e.g. many pollution effects become noticeable only after some time).



Source: European Commission (1995). Extensions of the ExternE methodology to further fuel types and for the 15 EU member nations are ongoing.

Example 1: The **ExternE** study funded during the early 1990s by the European Commission under the JOULE programme sought to provide an operational accounting framework for estimates of the externalities – the negative or positive impacts on natural capital and on human health – associated with the energy supply sector. Analyses have been mainly at project and process levels, but these can be extrapolated for whole sectors or national economies. ExternE focused initially on coal and nuclear fuel cycles, and then oil and gas fuels, hydroelectricity and wind power. The study employed the 'Impact Pathway Approach'. This is a step-by-step method starting from a particular fuel cycle stage and its emissions, and moving through their interactions with the environment to a physical measure of impact and – where desired and possible – monetary valuation (see Box 2). In the last stage a monetary value is placed on the physical damage linking it with a certain dose of pollutant, thereby crossing the Monetisation Frontier. Strong assumptions about comparability of different goods and bads are required in order to estimate monetary values for all environmental damages and, in some fuel cycles, there are long-term impacts – notably global warming impacts from the fossil fuel cycles and the radiological health impacts of long-lived isotopes from the nuclear fuel cycle. Alternatively, the calculation of impacts in physical units gives environmental information that can be used in deliberative or decision support procedures such as multicriteria analysis, without necessarily crossing over into the monetised domain.

Figure 3: Concepts for environmentally adjusted macroeconomic indicators



Example 2 concerns green national accounting: the estimation of a **'green GDP' indicator** at the macroeconomic level. Since the 1980s various methods have been developed for indicators of a nation's economic and environmental performance (see also Policy Research Brief 9). The principal concern is to include changes in natural capital in the annual accounting of a nation's production and consumption. Two main concepts have emerged for defining environmentally adjusted macroeconomic indicators:

- The first approach is to change the economic system boundary. This involves an enlargement of the scope of monetary national accounting to include specified categories of environmental assets. Using Figure 3, this can be thought of as shifting the frontier (moving from the solid horizontal line to the dashed line) dividing the economy from its external environment. This shift brings some natural capital (such as minerals, oil and gas, forest or fisheries stocks) into the field of economic monetary accounting, signalled by the arrows pointing downwards. The accounting procedures focus on the changes in natural capital, and these may be valued either from the supply side (such as economic costs of restoration or of avoiding depletion) or from the demand side (such as economic actors' willingness-to-pay to maintain the asset).
- The second concept is to adjust the economy itself. The result is a 'greened' economy with production processes and levels of production and consumption respecting specified environmental performance standards. In Figure 3, the focus is on the interface between the economic system and its environment, the horizontal line which is kept invariant as the Monetisation Frontier. Changes in natural capital are quantified in non-monetary terms, using indicators of the state of the environment (such as fisheries population levels) and of pressures on the environment (such as freshwater extraction rates or pollutant emissions). The policy goals are set directly with reference to the state and pressure indicators.

Environmental Systems Dynamics and Critical Natural Capital

Environmental policy is frequently organised using the **pressure-state-response** framework of analysis. In this model, the pressures are human activities of production and consumption affecting the environment (e.g. oil and mineral extraction, fertiliser applications); the state refers to observable changes of the environment (e.g. global mean temperature rise, algae growth in lakes); the responses are the measures proposed or implemented by society to deal with the problem.

The well-known **Ehrlich formula** gives a simple and intuitive approach to the pressure problem. It links ways of life, as parameterised by indices of consumption, and impact on the environment. Ehrlich wrote **I = PxCxT**, where **I** is the total environmental impact, **P** is the relevant (human) population, **C** is the typical consumption per person within the society or region or sector being studied, and **T** is the environmental impact per unit of consumption. So **I** is a generic pressure indicator. This approach is very general. Specific pressure indicators can be developed for different categories of consumption or environmental pressure such as energy and natural resource use or space requirements. Given the variety of policy problems and stakeholders, many different scales of change are relevant. Moreover, there are usually contrasting perspectives with regard to the effects of changes in the system. Changes judged as improvements for certain social groups over a certain time horizon can be a step back for others, or attributed to a different time-scale.

Hueting (1980) has promoted a comprehensive approach. He characterised the environmental pressures with reference to **environmental functions** of direct and indirect significance to humanity. The physical environment is considered as a complex natural system consisting of:

- processes (the internal regulation, cycles of renewal, evolution and transformation by which biosphere activity is maintained); and
- services (the environment's functions for the human economy).

There is as yet no universally accepted general framework for taxonomy. However, based on the work by Hueting and, more recently, by De Groot (1992) and others, it is now common to regroup the main types of environmental functions under broad categories, such as the five **S**'s:

- **S**ource of biological resources, food, raw materials and energy in various forms;
- **S**ink, or place of controlled and uncontrolled disposal of 'waste' products and energy of all sorts;
- **S**cenery, covering all forms of scientific, aesthetic, recreational, symbolic and informational interest;
- **S**ite of economic activity (including all forms of land uses and occupation of space for transportation);
- Life–**S**upport for human and non-human living communities.

Appraisal of changes in environmental systems in terms of their ecological, economic and social significance first requires observation of the natural processes and ecosystems in question (see Box 3). Such observations necessarily draw on concepts borrowed from natural philosophy, ecosystems science and related disciplines. In recent decades, a variety of important concepts of ecosystems dynamics have been developed around

Box 3: Examples of the Variety of Environmental Functions and Natural Capital Components

Primary energy sources: Thermodynamically available energy is an essential component of all economic production. While substitution between energy forms is generally possible, the complexity of energy infrastructures and related land uses makes it important to distinguish major subcategories: fossil fuels (coal, oil, gas), uranium and other fission fuels, solar energy captured through photosynthesis, hydroelectricity, wind, tidal energy, geothermal heat, and so on.

The atmosphere as multifunction life-support system: The functions are critical in several dimensions: the air that we breathe; acid rain; the protective ozone layer; atmospheric circulation and its implications for climate stability/change.

Forest ecosystems: On a large scale, forest ecosystems are an important component of atmosphere renewal and purification; this includes their role as carbon sinks. At the local scale, forest cover may also be important for stabilising soils, groundwater quality, retention and flood control, and nutrient recycling. Forests may also be economically or culturally critical as habitats and as food and energy sources.

Freshwater resources: Water supply for drinking, irrigation and other uses has always been a determining factor in the localisation of human habitats. Water must be available on a daily basis. Since watersheds are demarcated geographically and transportation is costly, water resource depletion or degradation are similarly localised.

Wild and agricultural genetic diversity: The importance of genetic resources in general (wild resources, improved traditional varieties, modern varieties and genetically engineered varieties) can be a matter of possible future economic interest, or based on ethical and precautionary principles. Agricultural genetic diversity has arisen in the course of farming societies through hundreds of years of husbandry practices, and this 'cultivated natural capital' usually requires, for its perpetuation, to be complemented by wild relatives and ecosystems.

organisational stability and thresholds of instability. Two well-known examples are Holling's theory of resilience, and Prigogine's far-from-equilibrium thermodynamics (linked to concepts such as chaos, multiple equilibrium and bifurcation).

For over 30 years ecologists and systems scientists – such as Pimm, Schneider and Kay, and Holling – have explored different concepts of ecosystem (stability, change, diversity and resilience) as a function of internal structuring and external influences. This work has many important insights for human sustainability concerns (see also Policy Research Brief 1). Complexity is a recurring theme (see also Policy Research Brief 2) emphasising interplay of distinct forms and forces at different organisational scales rather than any simple hierarchy. Two areas of analysis are of particular concern: first, the investigation of instability and resilience of natural systems under various sorts of perturbations by human agency, and second, the appraisal of the significance of the possible ecological changes for human interests. Quantitative predictions, however, are not usually possible. Ecosystem (and economic system) resilience is not a static concept or a simple yes/no-type property. Rather, economic and ecological systems coevolve and may undergo major changes in organisation at different scales. These changes may be gradual or dramatic. Sometimes a system (or sub-system at a given level of analysis) may 'flip' from one organisational state to another.

In economics environmental problems are framed as resource problems in the form of allocating scarce resources to maintain the desirable level of environmental functions. Contemporary ecological science tends to emphasise human activitiy as a dynamic force in the structuring and restructuring of ecosystems. Whatever concepts of ecosystems dynamics are adopted, policies must aim to safeguard the key environmental functions. This corresponds to a kind of social demand for the environment which may include provision for future generations and demand for protection from environmental harms.

Many of the interested parties cannot be present or speak, and many of the benefits in question are diffuse in character. Often, operational specification can be achieved through defining environmental standards or norms that represent a society's aspirations for nature conservation and for the delivery of the ecological welfare base to present and future generations. Emphasis is then placed on defining the economic resource opportunity costs associated with the achievement of specified environmental quality goals. This is the approach taken by the recently completed **CRiTiNC** project (see Box 4) with case studies treating selected categories of and thresholds for 'critical natural capital' (CNC). CNC is defined as any set of environmental resources which, at a prescribed geographical scale performs important environmental functions and

Box 4: The CRiTiNC Diagnostic Framework for Sustainability Analyses

The multi-country research project CRiTiNC was funded during 1998–2000 by the European Commission and co-ordinated by Paul Ekins and Sandrine Simon at the University of Keele in England. It refined and tested a framework for identification of environmental functions and categories of critical natural capital in relation to sustainability requirements. Four levels of analysis were identified as being linked to each other.

Level 1 defines the parameters (characteristics) of the ecosystems being studied, so as to describe their capacities to provide certain functions. This aims to illustrate the links between ecosystem functioning in itself (such as food chains and nutrient cycles, physical transport process) and the environmental functions or services furnished to human societies.

Level 2 describes economic sectors and their effect on environmental functions. More specifically, it analyses the environmental pressures caused, directly and indirectly, by different categories of economic activities.

Level 3 presents requirements for sustainability in its various dimensions (economic, environmental, ecological, social and cultural) at the scale of analysis. Thresholds, standards and targets are proposed in relation to specific economic activities, ecosystem functioning and the services they provide for societies and the interfaces between economic and ecological activities.

Level 4 makes the comparison between the standards given in Level 3 and the current impacts or state indicators described in Level 2. It allows the identification of sustainability 'gaps' corresponding to the distance between the current situation and sustainably managed resources. Examining the various gaps is the basis for analyses of technological, land use and other response options.

Source: CRiTiNC website, http://www.keele.ac.uk/depts/ge/CRITINC/critinchome.htm

for which no substitute exists (manufactured, human or other natural). Applying this concept requires detailed appraisal of the roles and significance of different natural capital systems for supporting economic activity and identifying the destructive environmental effects of each economic use/user category. If this information can be obtained, it is possible to specify spatial and temporal scales for which certain environmental functions and, hence, the natural capital systems may be critical, taking note of social and cultural factors that may contribute to making these of 'critical' importance.

The **English Nature** example in Box 5 shows that policies for sustainability are increasingly based on setting targets of non-depletion or non-degradation of existing environmental functions. The same idea applies under the rules for harvesting renewable resources below the regenerative capacity of the environment.

However, there are many difficulties in the operationalisation of this framework. A single ecosystem or natural resource might fulfil a range of functions. There can be some controversy over scientific justifications for the threshold levels or 'norms' that are proposed due to the complexity of ecosystem processes and differing perspectives over the extent to which a function is 'critical' or not. In addition, sustainability policy targets will always have both social and ecological dimensions. For example, even if the ecological and economic requirements of tropical forest were well-known, questions still arise about stewardship of which forests, where and for whom? Non-built environments are often valued for recreational, aesthetic and spiritual reasons. Their conservation and enhancement may be motivated by ethical convictions of respect and coexistence. Communities may identify features of their habitats as 'critical' natural capitals in view of their symbolic or functional significance in defining group identity.

Once environmental threshold standards are set 'gaps' between the identified sustainability requirements and the current situation can be estimated. Resource management may then be approached in terms of cost-effectiveness analysis. The goal is to find low-cost and effective ways of achieving the defined norm, perhaps through a transition lasting years or decades. The information organised by the CRiTiNC framework can thus support scenario studies and multicriteria appraisal in which a range of priorities and strategies (based on differing, and potentially conflicting, views) for maintaining environmental functions can be expressed and jointly analysed.

Yet setting environmental policy targets is usually a conflictual process. The policy process must also address issues of distributional justice and conflict resolution. For example, restrictions on fisheries catch entitlements or on water resources extraction in respect of renewability rates, may aggravate social inequalities (who will get privileged access?). A wind-farm is a way of decreasing the loss to the resource base of the economy by the use of a renewable resource; at the same time it is potentially visually damaging to the landscape. Titanium mining in southern Madagascar may be profitable for corporations, but may also perturb and contaminate coastal fisheries ecosystems; what investments in the sustaining of local subsistence communities will be offered in compensation? After the mining has passed, a replanting operation may take place. This may be defined as a reforestation; but of what species, with what local economic and ecological utility, and with what future cutting rights? These are examples of issues of the (unequal) distribution of (un)sustainability. Environmental knowledge alone does not suffice.

Box 5: Constant Natural Assets and Critical Natural Capital

Since the early 1990s, the environmental agency English Nature has developed and tested a variety of classification schemes and proposed policy rules for the maintenance of environmental functions. They argued as follows (English Nature 1995, p. 2):

> "The UK's current stock of environmental assets represents a level from which there should be no further net loss in quantity or quality if environmental sustainability is to be achieved. It is made up of Critical Natural Capital and Constant Natural Assets. Our Critical Natural Capital comprises those assets which are irreplaceable. Our Constant Natural Assets are made up of environmental features which may be traded in issues of land use change, but the loss must be fully and directly compensated to give no overall loss."

The work focused on establishing a basis for identifying Critical Natural Capital (CNC). For the terrestrial environment, four broad categories are identified:

- habitats supporting rare, threatened or declining species;
- ecosystems that have full expression of a characteristic biodiversity;
- environmental service provision such as stabilisation of soil, assimilation of wastes or maintenance of water table and water quality features;
- earth sciences interest, meaning formations of exceptional geological interest or unique character.

For each of these categories, a decision tree has been established allowing a selected piece of the natural environment to be classed as CNC if they are (i) essential for human health and/or for the functioning of life support systems, and (ii) irreplaceable or practically unsubstitutable. The envisaged policy rule is that CNC assets that are irreplaceable must be afforded the strictest protection.

The concept of Constant Natural Assets (CNA) brings together two interesting features. First, in the term 'constant' a normative rule is implied. Second, although possibilities of replacement, restoration or re-creation are admitted, a very cautious approach is taken towards aggregation and substitution. The normative policy rule follows the criterion of a 'non-negative change' to natural capital as enunciated in the academic economics literature, viz., "The overall levels of our CNA must not decline – in some cases they must increase" (English Nature 1995, p. 6). But no attempt is made to compare very disparate types of natural assets. The idea is that, for example, an area of woodland can be cut down or built upon, or a bird habitat diminished, if a compensating area of similar forest or habitat is elsewhere established. 'Compensation' is permitted only within each class of natural asset or identified environmental function.

The combined CNC and CNA approach is very close to the rule of 'maintaining key environmental functions intact' as enunciated by Hueting and others.

From Information to Deliberation

Information and communication frames must be assessed not just from the viewpoint of scientific validity, but also (and more particularly) from the viewpoint of the ways that they can contribute to processes of conflict and resolution. Learning about economic and environmental issues involves confronting a diversity of objectives and interests which are expressed in a variety of vocabularies and at different scales.

Take the example of nitrate and pesticide pollution from agricultural activities. Data may be available on total chemical applications in a given region. This can be the basis for a 'pressure' indicator. However, the effect on local ecosystems and water quality, for a given quantity of fertiliser or pesticide applied, is highly sensitive to factors such as topography, rainfall and wind, soil properties and history of past agricultural exploitation. Aggregation can involve tremendous losses of information quality. What matters is the learning about natural systems, technological potential, economic systems and policy processes that can take place through construction and comparison of the information sets, models, indicators and scenarios. This must be linked back to an appreciation of the significance to different groups and persons of alternative resource management choices – including, in some cases, choices to *not* manage particular processes, ecosystems and resources.

Figure 4 sets systems science in complement with social significance. In effect, the social (existential, cultural, political) dimensions define the contours of the models and frameworks used to organise scientific figures and facts.

Figure 4. The semantic field for sustainability studies

SYSTEMS SCIENCE (Feasibility)	Information, Indicators (and Uncertainties)	INTEGRATION and DELIBERATION	Social Actors (Stakeholders)	SOCIAL SIGNIFICANCE (Desirability)
Resources and Techniques	Analytical Methods for Option Appraisal	POLICY ISSUES (Sustainbility for what and for whom?)	Motivations, Interests (and Justifications	Ethics, Culture and Values

- *Assessing feasibility* involves considerations of interacting economic and ecological systems. This may entail various forms of systems representation, simulation modelling and quantification that, for example, would permit to portray responses to the question 'sustaining of what and for whom?' This is the realm of traditional efforts at integrated modelling combining ecological and economic dimensions for scenario studies.
- *Assessing desirability* involves attention to different stakeholder preoccupations and experiences at the level of individuals and groups and, at larger scales, collective purpose, political regulation, governance and conflict management.

Conflict management means political processes. Over the last twenty years a variety of **multiple criteria decision aid (MCDA)** methods have been developed and applied in efforts to help organise scientific and economic information as a basis for environmental decision-making. MCDA methods do not provide a unique criterion for choice, rather they help to frame the problem of arriving at a societal/political compromise. Alternative courses of action are delineated and judged on the basis of different evaluation criteria and their relevance for affected interest groups (see also Policy Research Brief 2). This can help to identify what the most important trade-off considerations and sticking points in negotiations will be.

Valuation research that specifically sets out to develop the social context for decisions or policy advice is also relevant. This takes account of the fact that the character of valuation statements and decisions reached depends a lot on the social and political processes. Discursive processes such as focus groups, or deliberative procedures such as mediation and citizens' juries, can be employed in extended fashion – sometimes with the aid of multicriteria frameworks and computer-based simulation technologies – to enable imaginative construction of social, economic, ecological futures. Deliberative institutions for resolving conflict and for exploring possible futures are examples of collective processes for environmental governance. In such processes, people's valuation judgements are embodied in the agreements reached (or the disagreements made more plain) through argument and practical judgement.

A social learning or stakeholder concertation process can be developed (see Figure 5) that integrates systems science with stakeholder deliberation in a recursive cycle as follows:

- Step 1: Diagnosis of stakeholder interests and first specification of the resource management problems to be solved.
- Step 2: Scientific analysis of the key ecosystems and environmental processes (e.g. hydro-system modelling, marine population ecology).

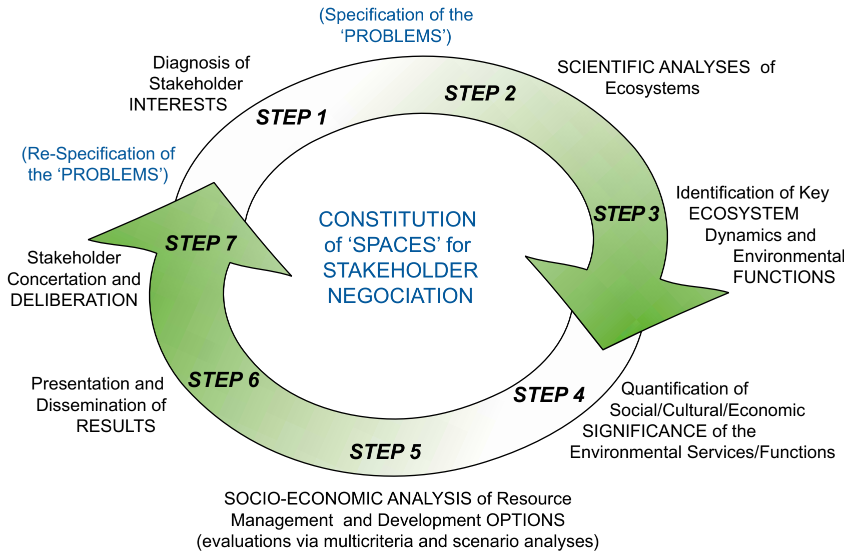


Figure 5.
The deliberation cycle for integrated policy analysis

- Step 3: Analysis in biophysical terms of the environmental functions of the resource (e.g. in the broad categories of source, sink, site, scenery and life-support).
- Step 4: Representation and quantification of socio-economic significance of environmental functions (the services rendered to economic activity and human well-being).
- Step 5: Socio-economic analyses of resource use options, using multicriteria appraisal and scenario analyses perspectives with stakeholder participation.
- Steps 6 and 7: Communication of results (resource management options, evaluation results, and so on) and stakeholder appraisal, leading to re-specification of key problems and options.

The emphasis is on the real-time process of sharing information – that is, expressing and communicating about interests, knowledge, disagreements and possible solutions.

When, as in the current classes of major environmental problems, uncertainties and decision stakes are high, a new approach is appropriate. Given the impossibility of resolving in a decisive manner the scientific uncertainties, and given the wide divergences that can exist between stakeholders as to what matters and why, it is necessary to reconsider the question of who can and should be a legitimate participant in the evaluation process. This leads to the notion of an extended peer community (Funtowicz and Ravetz 1990), including all stakeholders in an issue who are prepared for a dialogue, regardless of their formal certification.

Key Points

This policy research brief has reviewed some of the frameworks that have emerged in systems science, ecological economics and environmental accounting for organising information about the physical environment and ecosystems as a support for sustainable development policies.

- **Natural capital** has been defined as any element or system of the physical world which, directly or in combination with produced economic goods, furnishes materials, energy or services of value to society.
- The concept of **critical natural capital** has been outlined, referring to any set of environmental resources which at a prescribed geographical scale performs important environmental functions and for which no substitute in terms of manufactured, human or other natural capital currently exist.
- Emphasis is placed on ecosystems (and the biosphere more generally) as **dynamic processes**, and on economic activity as embedded within these inter-dependent ecological and geophysical processes.
- Analysis for **sustainability** purposes must give attention to (i) the functioning of these systems and (ii) their roles or functions for the support of economic activity and human well-being.
- The heuristic concept of the **Monetisation Frontier** has been introduced, this being the 'boundary' that divides the domains in which environmental information is put in monetary terms, from the domains where information in organised in a variety of non-monetised forms. Generally speaking, work on both sides of a monetisation frontier is necessary for effective environmental policy. For example, the identification of 'critical' components of natural capital or of key 'environmental functions', can be a basis for defining sustainability standards, thresholds and performance goals. Then economic analyses can be conducted about the costs and benefits, including distributional consequences, of different strategies for reaching these goals.
- The variety of economic interests, stakeholder preoccupations and ethical convictions within and between societies makes conflict inevitable. If inclusive solutions are sought, then social learning or stakeholder concertation processes can be developed that **integrate systems science with stakeholder deliberation**. Such procedures may include the use of economic valuation techniques, where appropriate. But there is no single category of information, monetary or non-monetary, against which all economic, biological, aesthetic and cultural values that inform different choices can be put on a common scale. The different criteria, such as principles of justice, or concerns for economic efficiency, or human and environmental health, can be put forward and their implications explored. Discursive and deliberative processes can be particularly useful for investigating underlying value issues that divide or unite communities of place or interest, and for enabling the stakeholders in question to contribute to conflict resolution processes.
- Effective use of environmental information for developing sustainability policies must confront distinctive challenges of **knowledge quality assessment**, including differences in underlying values, working with uncertainty and indeterminacy (and the tension between foresight and adaptation), and the multiple spatial scales and time horizons.

References & Further Reading

Berkes, F. and C. Folke (1992) 'A systems perspective on the interrelations between natural, human-made and cultural capital', *Ecological Economics* 5(1): 1–8. *Useful discussion of notions of natural capital in relation to social systems, institutions and policy*

Carson, R. (1960) *Silent Spring*, reprinted by Penguin Books, 1965. *Recognised as a classic, a lucid exposition of the prospects of large-scale species extinction through indiscriminate use of chemical pesticides*

Ciriacy-Wantrup, S.V. (1952) *Resource Conservation: Economics and Policies*, Agricultural Experiment Station, Berkeley: University of California Press. *A lucid economist's discussion of the precautionary basis for environmental policy in the face of ecosystem complexities and uncertainty*

Common, M. and C. Perrings (1992) 'Towards an Ecological Economics of Sustainability', *Ecological Economics* 6: 7–34. *Article bringing systems stability and resilience concepts into reflections about environmental policy*

Daily, G.C. (ed.) (1997) *Nature's Services: Societal Dependence on Natural Ecosystems.* Island Press, Washington DC. *Essays from various disciplinary perspectives, including D. Tilman on the significance of species diversity for ecosystem functioning*

Daly, H. (1994) 'Operationalising sustainable development by investing in natural capital'. In A.-M. Jansson, M. Hammer, C. Folke and R. Costanza (eds) *Investing in Natural Capital: The Ecological Economics Approach to Sustainability.* Washington DC: Island Press, pp. 22–37.

De Groot, R.S. (1992) *Functions of Nature*, Wolters-Noordhoff, Amsterdam. *Systematic development of the concept of environmental functions, adopted from Hueting, for the analysis of the ways that economic activities depend on natural systems*

De Marchi, B., S. Funtowicz, S. Lo Cascio and G. Munda (2000) 'Combining Participative and Institutional Approaches with Multicriteria Evaluation. An Empirical Study for Water Issues in Troina, Sicily', *Ecological Economics* 34(2): 267–284. *Case study using multi-criteria and interactive social science methods for natural resource management and environmental governance issues*

Ekins, P. and S. Simon (1999) 'The Sustainability Gap: A practical indicator of sustainability in the framework of the national accounts', *International Journal of Sustainable Development* 2(1): 32–58. *The use of 'strong sustainability' standards for formulating resource management policies*

English Nature (1995) *Establishing Criteria for Identifying Critical Natural Capital in the Terrestrial Environment: A Discussion Paper*, English Nature Research Report No. 141, Peterborough, UK, prepared by James Gillespie and Peter Shepherd.

European Commission (1995) *ExternE: Externalities of Energy, Vols.1–5: Summary, Methodology, Sectoral Analyses*, Report EUR-16520, European Commission, Brussels.

FAO (1999) *Indicators for Sustainable Development of Marine Capture Fisheries*, FAO Technical Guidelines for Responsible Fisheries No. 8, Rome. *Succinct and practical outline of ways of organising information systems for fisheries governance*

Faucheux, S. and M. O'Connor (eds) (1998) *Valuation for Sustainable Development : Methods and Policy Indicators*, Edward Elgar, Cheltenham. *Presents a variety of conceptual frameworks and applications – including 'weak' and 'strong' sustainability concepts, energy-based systems analysis, multicriteria methods and multisector scenario modelling – for policy-oriented analyses of economy–environment interfaces*

Faucheux, S., M. O'Connor and J. Van der Straaten (eds) (1998) *Sustainable Development: Concepts, Rationalities, Strategies*, Dordrecht: Kluwer. *Collection of essays that assess, inter alia, prospects and limits of using monetary figures for appraisal of environmental change and sustainability prospects confronting uncertainty, distributional conflicts and systems complexity*

Funtowicz, S.O. and Ravetz, J.R. (1990) *Uncertainty and Quality in Science for Policy*, Kluwer, Dordrecht.

Holling, C.S. (1986) 'The resilience of terrestial ecosystems: Local surprise and global change' in W.C. Clark & R.E. Munn (eds) *Sustainable Development of the Biosphere*, Cambridge University Press, pp. 292–317. *Entrée to Holling's ecosystems dynamics theory and its lessons for management approaches*

Hueting, R. (1980) *New Scarcity and Economic Growth: More Welfare through Less Production?*, North-Holland, Amsterdam. *By one of the pioneers of methods for integrated analysis of environmental impacts of economic activity and policy responses for sustainability, including the notion of competition for scarce environmental functions*

Jansson, A.-M., M. Hammer, C. Folke and R. Costanza (eds) (1994) *Investing in Natural Capital: The Ecological Economics Approach to Sustainability*, Washington D.C.: Island Press. *Collection of papers on the importance of natural capital for sustainability policy*

Martinez-Alier, J. (1987) *Ecological Economics*, Basil Blackwell, London. *Comprehensive history of ways that heterodox economic thinking since the 19th century has sought to exploit physical and biological sciences knowledge for understanding 'biophysical foundations' of society*

O'Connor, M. and C.L. Spash (eds) (1999) *Valuation and the Environment: Theory, Methods and Practice*, Edward Elgar, Cheltenham. *Collection of essays on methodological issues and empirical studies using monetary valuation techniques and a variety of non-monetary information and appraisal techniques*

O'Connor, M. (2000) 'Pathways for environmental valuation: A walk in the (hanging) gardens of Babylon', *Ecological Economics* 34(2): 175–194. *Application of notions of complexity and social sciences epistemology for policy-oriented analysis*

Passet, R. (1979/1996) *L'Economique et le Vivant*, 2nd edition 1996, Economica, Paris. *An excellent exposition, in French, of the application of open systems concepts for understanding challenges of economic analysis and policy in their institutional and wider ecological contexts*

Pearce, D. (1976) 'The limits of cost-benefit analysis as a guide to environmental policy', *Kyklos* 29: 97–112. *One of the precursors of the 'Frontier of Monetisation' idea*

Peet, J. (1992) *Energy and the Ecological Economics of Sustainability*, Washington D.C.: Island Press. *Exposition of the insights from thermodynamics and energy analysis for framing the technological, political and ethical challenges of sustainable development*

Pimm, S.L. (1991) *The Balance of Nature. Ecological issues in the conservation of species and communities*, University of Chicago Press, Chicago. *Exploration of stability and resiliency concepts for analysing multi-species ecosystem dynamics*

Prigogine, I. and I. Stengers (1984) *Order out of Chaos*, Heinemann, London. *Popular exposition of the 'far-from-equilibrium' thermodynamics and concepts of dissipative systems*

Schneider, E. and J.J. Kay (1994) 'A new ecology', *Futures* 26(6): 626–647. *Useful introduction to some open systems perspectives on ecosystems analysis*

EVE Concerted Action

ADDRESS

Cambridge Research for the Environment, Department of Land Economy,
University of Cambridge, 19 Silver Street, Cambridge CB3 9EP, UK

Fax. +44 (0)1223 337130

Webpage: http://www.landecon.cam.ac.uk/eve/

Concerted Action on Environmental Valuation in Europe (EVE)

This policy briefing series communicates the findings from nine workshops and three plenary meetings under the EVE programme. These showed the diversity of research currently being undertaken in the area of environmental values and their policy expression. The type of information relevant to the decision process extends from ecological functioning to moral values. Thus a range of approaches to environmental valuation, from ecology to economics to philosophy were presented.

EVE was a 30 month project which started in June 1998 funded by the European Commission, Directorate General XII within Area 4, Human Dimensions, of the Environment and Climate RTD programme, Contract No. ENV4–CT97–0558.

The project was co-ordinated by Clive L. Spash and managed by Claudia Carter, Cambridge Research for the Environment (CRE) in the Department of Land Economy, University of Cambridge. The following research institutes were partners in the concerted action:

Bureau d' Econonie Théorique et Appliquée (BETA), University Louis Pasteur, Strasbourg, France
Cambridge Research for the Environment, Department of Land Economy, University of Cambridge, UK
Centre for Human Ecology and Environmental Sciences, University of Geneva, Switzerland
Centre d'Economie et d'Ethique pour l'Environnement et le Développement (C3ED), University of Versailles Saint-Quentin-en-Yvelines, France
Centre for Social and Economic Research on the Global Environment (CSERGE), University of East Anglia, Norwich, UK
Department of Economics and Economic History, Autonomous University of Barcelona, Spain
Department of Economics and Social Sciences, Agricultural University of Norway, Åas, Norway
Department of Environmental Economics and Management, University of York, UK
Department of Philosophy, Lancaster University, UK
Department of Rural Development Studies, Swedish University of Agricultural Sciences, Uppsala, Sweden
Department of Applied Economics, University of Laguna, Tenerife, Canary Islands, Spain
Environmental Economic Accounting Section, Federal Statistical Office, Wiesbaden, Germany
Ethics Centre, University of Zurich, Switzerland
Fondazione Eni Enrico Mattei (FEEM), Milan, Italy
Istituto di Sociologia Internazionale di Gorizia (ISIG), Gorizia, Italy

The purpose of this concerted action was to analyse effective methods for expressing the values associated with environmental goods and services, ecosystem functions and natural capital, with a view to the achievement of the goals summarised in the concept of sustainability. The appropriate role of decision-makers and citizens in environmental policy-forming became a central focus in the debate over how different values should be expressed.

Titles in the EVE Policy Research Brief Series:

1 **The Concerted Action on Environmental Valuation in Europe (EVE): An Introduction**
by Clive L. Spash

2 **Conceptualising and Responding to Complexity**
by Giuseppe Munda

3 **Natural Capital**
by Martin O'Connor

4 **Conceptions of Value in Environmental Decision-Making**
by John O'Neill & Clive L. Spash

5 **Conceptualising Sustainability**
by Anton Leist & Alan Holland

6 **Property, Rights and Fairness**
by Roderick Lawrence

7 **Environmental Quality, Health and the Value of Life**
by Marc Willinger

8 **Value Transfer and Environmental Policy**
by Stale Navrud & Olvar Bergland

9 **Greening National Accounts**
by Martin O'Connor, Anton Steurer & Marialuisa Tamborra

10 **Participatory Approaches to Environmental Policy**
by Bruna De Marchi & Jerome R. Ravetz

11 **Environmental Valuation in Europe: Findings from the Concerted Action**
by Clive L. Spash & Claudia Carter