Valuation of Natural Resources: A NERC Scoping Study

Final Report

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Executive Summary

Aims

The Natural Environmental Research Council (NERC) identified the need to review the existing evidence base to support its strategic priorities in its Science Theme for the **S**ustainable **U**se of **N**atural **R**esources (SUNR), particularly with respect to the valuation of **n**atural **r**esources and related **e**cosystem **s**ervices (referred to here as NRES).

In this context, the broad purpose of this scoping study is to inform NERC strategies on the valuation of NRES, thereby enhancing the Council's potential contribution to achieving sustainable development.

The study aimed to produce a 'state of the science' review of valuation in terms of what exists, what is being done, how well it works and perceptions of likely future needs and future priorities.

Approach

A variety of methods was used to assess the current state of valuation with respect to NRES. These included a search of academic literature, email questionnaires, and semi-structured interviews with senior researchers involved in valuation studies.

A number of dedicated web-based research inventories and project sites were reviewed that facilitate information and knowledge exchange regarding NRES valuation, including data, methods and results. Responses to an email questionnaire survey were obtained from 35 researchers involved in NRES valuation, followed up by telephone interviews with 10 researchers, 5 of whom had replied to earlier correspondence and 5 of whom were newly contacted. Thus approximately 40 respondents were involved in total.

It transpired that a formal review of the way that risk and uncertainty has been handled in NRES valuation research was not possible within the resources available, but this topic was covered during the survey of researchers.

Main types and applications of NRES valuation research

From a human perspective, the term **value** implies something that is good and pleasurable. This view of value is largely 'instrumental' in that something is good because of the benefits it bestows to people. **Valuation** is the process by which values for goods and services are obtained. An obvious basis for value is that given by the willingness to pay and receive payments for items exchanged in market transactions. However, many of the flows of goods and services associated with natural resources are non–market, public goods for which prices and monetary values are difficult, and in some cases impossible, to obtain.

A review of academic and grey literature showed that a range of techniques has been developed and used for the valuation of NRES. Techniques fall into two broad types. One type involves methods of economic analysis that derive monetary values by exploring the impact of environmental change on incomes or costs, or by constructing surrogate markets to determine willingness to pay by citizens for environmental services. The other type involves deliberative/participatory methods which seek to elicit values and preferences for environmental goods and services through discourse and knowledge exchange with citizens.

Deliberative methods have been developed partly in an attempt to overcome the perceived limitations of economic valuation methods.

The review confirmed the potential advantage of adopting an ecosystems framework to represent the diversity of service flows and provide a basis for valuation. It was noted however, that the valuation of NRES is made difficult by inherent uncertainties associated with the response of ecosystems to anthropogenic pressures. These can generate gradual or catastrophic failure in ecosystems, with consequences for human welfare. Explicitly building in allowance for, and communicating the inherent uncertainty associated with ecosystem dynamics, is an important element of NRES valuation.

With respect to research domains, the review of electronic data bases showed that the most frequently occurring keyword descriptors associated with NRES valuation tend to be land-based, concerned with "land", "forests", "agriculture" and "landscapes", followed by those referring to "water" and "wetlands". By comparison, energy is relatively under-researched as a NRES topic. NRES valuation research is dominated by the USA, but there has been a steady growth of capacity in the UK and Europe as a whole.

Perceived capacity in NRES valuation

The vast majority of valuation research uses economic, monetisation valuation methods, especially using contingent valuation. The most frequently used decision support method used in valuation research is Cost:Benefit Analysis. More recently the reported use of deliberative methods has grown, typically associated with large multi-agency research programmes.

A review of NRES related projects showed that the main types and applications of valuation research are heavily focussed around the concept of ecosystem services, integrated biophysical modelling, interdisciplinary approaches, and stakeholder engagement. Most projects are developing data and methods which are potentially relevant for policy management. Some projects are particularly oriented towards end-user support. The Environmental Valuation Reference Inventory (EVRI), for example, provides a structured information base that supports the transfer of primary benefit estimates to secondary applications. In this respect, there is a growing international capacity in NRES valuation that contributes to the design, appraisal, implementation and evaluation of policy interventions. There is scope to enhance this in the UK.

Most researchers engaged in NRES research reported that they thought methods and data were, for the most part, suitable for the purposes of NRES research and outcomes. There was a call for greater integration of data sets to support integrated modelling, especially in GIS format. There was growing interest and capability in the integration of quantitative and qualitative methods, combining for example Cost:Benefit analysis with participatory methods, supported by developments in visualisation technologies.

Stakeholder interest in NRES valuation

There is heightened awareness of the importance and potential instability of the relationship between natural resources and human welfare, evident in recent scientific reviews such as the Intergovernmental Panel on Climate Change (IPCC), Millennium Ecosystem Assessment and the Stern Review. As the leading UK research body on natural sciences, NERC's strategic science theme on the Sustainable Use of Natural Resources includes a commitment to valuing environmental services.

A review of stakeholder interests drawn from reviews of literature, projects and correspondence with researchers shows a wide range of interest in the topic, incorporating international, national and local government and development agencies, regulatory organisations, non-government organisations, insurance and finance organisation, corporate bodies and other researchers. Most of the interest in the use of NRES valuation results is associated with appraisal of project development and/or policy options. This interest tends to find expression in research sponsorship, and as a result key interests tend to line up with the main influences on the research agenda.

It is true that to date, greatest interest and influence has been expressed through the sponsorship of economic appraisals. There are signs that this is changing in favour of more deliberative participatory methods, especially through large-scale integrated research projects. International and national development agencies are also showing much interest in NRES valuation reflecting greater commitment to citizen participation and to policies that promote social and environmental, as well as economic outcomes.

Main challenges with respect to data, methods and expertise

Most of the surveyed respondents involved in NRES valuation research reported that the integration of the science presented some problems, although half of them thought that these problems could be overcome relatively easily. It was considered that much progress had been made in recent years in interdisciplinary approaches to NRES valuation. Progress had been made drawing on funding associated with international and national funding programmes, such as EU projects which also included non-EU participants, and RELU-type national programmes. There remained some challenges to ensure that incentives, rewards and support were available for those who engaged in multi-disciplinary research, especially younger scientists.

The majority of respondents thought that existing data and methods were broadly fit for purpose, but there was scope for improving coverage and quality to provide more complete and robust estimates of value. There was some concern about quality assurance in NRES valuation and a need was identified for best practice guidance on the use and evaluation of valuation methods for project and policy appraisal.

For the most part, researchers thought that the ecosystems framework helped to construct an understandable and potentially comprehensive approach for the valuation of natural resources.

Review of literature and correspondence with experts identified priorities for future development of capacity in NRES valuation. These included:

- improved integration of existing data sets and of quantitative and qualitative valuation methods,
- continued development of integrated biophysical and socio-economic modelling of NRES at relevant spatial and temporal scales, addressing key areas of risk and uncertainty,
- improved quality control in the use of valuation methods, especially stated preference methods and benefit transfer,
- improved understanding of values through the use of deliberative participatory methods,
- more use of direct observations of actual behaviour, and
- improved understanding of the role of property rights and entitlements.

It was perhaps not surprising that those involved in NRES valuation considered it to be an essential component of a research strategy for the sustainable use of natural resources, and an essential component of policy relevant research. They saw it as a valid area for funding from a research body such as NERC. There was considerable support for an approach that provided long-term funding of relatively large projects that brought researchers from different sciences and applications together. They pointed to projects of this kind that had yielded success in terms of capacity building and research contribution.

Recommendations

Following this scoping study, a number of recommendations can be made for NERC regarding NRES valuation research as part of its support to the SUNR Science Theme. It is recommended that NERC should consider the following:

- The potential feasibility and advantage of adopting the ecosystems functions and services framework as a basis for guiding NRES valuation research that explicitly links the health and integrity of natural resources with the well-being of people and communities.

- The priority areas for future development, identified in the course of this study with a view to targeting key areas of support to the NRES valuation research community, including the balance between, and the integration of, economic and non-economic methods.

- How best to record, maintain, integrate and make accessible natural science (and related) data sets and asset inventories which can be used in NRES valuation research, including support to existing web-based providers of information services.

- The need for, and best way of providing, guidance on best practice and quality assurance of NRES valuation research

- Investment options for NRES valuation research, including the potential for long-term funding of collaborative, capacity building research projects organised under a Thematic Research programme that explicitly seeks to link the management of NRES with social well-being.

- How incentives, rewards and support can be marshalled to encourage innovative interdisciplinary research of the kind needed in NRES valuation, especially for young researchers.

- How, in the light of the observations made here, NERC Science Strategy can become more policy relevant, possibly setting up an Advisory Panel that manages the interface between NERC science and policy, and between NERC and other UK Research Councils.

Epilogue

NERC research in the area of valuation has much to offer in the strategic management of Natural Resources and Environmental Services, informing decisions on how people and communities can continue to prosper without irreversibly degrading the environment that supports them.

Chapter 1 : Introduction

This chapter describes the context, aims and objectives of the study of the valuation of natural resources and the flow of goods and services[1] that they provide.

Key messages

- There is heightened awareness of the importance and potential instability of the relationship between natural resources and human welfare, evident in recent scientific reviews such as IPCC, Millennium Ecosystem Assessment and the Stern Review.
- NERC's strategic science theme on the Sustainable Use of Natural Resources includes a commitment to valuing environmental services.
- There is an irrefutable case for integrating natural and social sciences in order both to inform and respond to societal values for the diverse range of goods and services provided by natural resources.
- This study sets out to produce a 'state of the science' review of valuation, exploring what is being done, how well it works, and what are the priorities for the future.

1.1 Context

Concern about the need to support a growing global population within environmental limits under threat of climate change, has heightened awareness and appreciation of the value of natural resources as they support human welfare. Human interaction with the global ecosystem has been increasingly staged through an economic system that has tended to under-value natural resources and the diverse range of goods and service that flow from them. It is recognised that continuation of current trends in resource use will no longer sustain humanity in a "full world". This has prompted the need to develop the "ecosystem approach"[2] to planning and development, which explicitly makes the link between the natural resources, ecological health and social well-being.

The 'ecosystem approach' developed by the Convention on Biological Diversity has been given major impetus by such reports as the Millennium Ecosystem Assessment (MA, 2005) and the Stern Review (2006). This has, however, created an urgent need to capture and represent the values of **n**atural **r**esources and related **e**cosystem **s**ervices (referred to here as NRES) in the processes of decision-making in ways that are both theoretically robust and practically workable. Such a need has been specifically indentified in the Guide to Valuation of Ecosystem Services recently published by Defra, 2007b. This not only applies at a high strategic level, such as for national energy or transport strategies, but also at the very local level of Town and Country Planning. Furthermore, there is a common lack of clear guidance on how best to incorporate values for NRES into existing policy commitments. The Water Framework Directive is a case in point, where approaches to valuation have emerged during

[1] While many commentators use the terms 'goods' and 'services' to distinguish between the more tangible and intangible outputs from ecosystems, others use them as synonyms. In this text we make no distinction between them and use the term 'services' to cover both.

[2] According to Potschin et al. (2008) it should be noted that the literature contains a number of variations in terminology designed to emphasise different aspects of the idea. Reference is often made to an 'ecosystem-based approach', a term used mainly to promote holistic thinking in the design of specific management strategies for natural resource systems. More commonly the term 'Ecosystem Approach' is employed. The latter originates from the Convention on Biological Diversity (CBD) and emphasises the higher-level or more strategic issues surrounding decision making. Defra, in a recent publications (e.g. Defra, 2007a), refer to an 'Ecosystem**s** Approach', using the plural to emphasise that no prescriptive methodology is implied. In this report we employ the terminology used by Defra – but see no substantive difference in the way the two ideas are conceptualised. In this report we also avoid abbreviating the term 'Ecosystems Approach' as 'EA' because it can be confused with the abbreviation for the Environment Agency; the IUCN CEM suggests using EsA as an alternative (written communication, 2007).

the process of policy implementation rather than policy design. Environmental Stewardship is another example. It seems entirely reasonable that the science of valuation of NRES should play a central role in the design and implementation of strategies to achieve sustainable development.

In this context, the Natural Environmental Research Council (NERC) has identified the need to review the existing evidence base to support its strategic priorities to "deliver world-leading environmental research at the frontiers of knowledge" as elucidated in the NERC Strategy "Next Generation Science for Planet Earth: NERC Strategy 2007-2012" (NERC, 2007). Indeed, this document sets the NERC Strategy in the context of the MA and Stern review to "fund the essential independent research at the frontiers of knowledge that will inform decision-making at all levels during this pivotal time". The Science Theme for the **S**ustainable **U**se of **N**atural **R**esources (SUNR) is aimed squarely at this goal, particularly with respect to natural resources and ecosystem services (NRES), with particular reference to valuation. The SUNR themes are:

Extending the Resource Base

This focuses primarily but not exclusively on the exploitation of energy from fossil fuels and also considers other non-renewable resources such as metals and minerals.

Meeting the Renewables Challenge

Renewable energy from wind and water energy are likely to play an increasingly important role. This challenge focuses on the problem of "placing renewable energy structures on the most effective sites", and seeks to "raise the profile of both the climate change and environmental implications of renewable energy in all its forms and to explore the multiple uses of sites as a method of enhancing their sustainability".

Sustaining Water and Soil Life Support Systems

This challenge focuses on interactions that occur at various scales for "sustaining the quality of air, soil, water interchanges that sustain life and support the biotic resources on which we depend. The challenge is to build integrated understanding across different space and time scales of the relationships between air/soil/water to inform sustainable use of this resource".

Valuing Environmental Services[3]

The objective of this Challenge is to improve decision-making through scientifically-informed choices and to "devise new and innovative methodologies to achieve parity for environmental services alongside readily quantifiable economic indicators".

There are also important valuation implications in the other science themes, notably Biodiversity which sets its Action Plan in the context of valuation studies and has as a "Valuing Biodiversity" as a priority action. Other actions such as "Ecosystem sustainability" will impinge on this, and Actions concerning "Monitoring" and "Mathematical Tools" will be

[3] Some commentators are arguing there is a major difference between ecosystem and environmental services. Although the terms 'environmental service' or 'landscape service' are less commonly used in the literature, they are probably more useful as a label to cover all the types of benefit that natural resources provide that are only weakly dependent on living organisms but which are clearly related to the abiotic characteristics of particular places. However for consistency we will use the term "ecosystem services" in the following text.

critical in providing the data and models necessary for informing planning decision support tools based on the valuation of ecosystem goods and services.

The context of the proposed scoping exercise is, therefore, the general conclusion, expressed in studies such as the Millennium Ecosystem Assessment (MA, 2005) and the Stern Review (2006), that the real values of NRES and related ecosystem services are inadequately represented in decision-making. This is not only because of market and policy failure, but also because approaches to valuation are often fragmented, partial and insufficiently complete. Dominant decision-making techniques such as cost-benefit analysis are known to inadequately accommodate the nuances and complexities of the interaction between the state of NRES and the well-being of human and other living systems. Furthermore, they are known to be biased towards particular measures of 'utility', especially those that lend themselves to monetisation.

For these reasons, it is imperative that ways are found to enhance the capacity for valuation of NRES. This requires improving (i) our understanding of the links between variations in NRES and human welfare, now and into the future; (ii) our understanding of the criteria and metrics for valuation and how these vary amongst different NRES, contexts, timeframes and social groups, and (iii) the ways of incorporating these often diverse values, and the underlying interests of those who hold them, into the main processes of decision-making, operating at different scales, national regional and local.

The need for effective valuation of NRES is also set in the wider context of the NERC's "Living With Environmental Change" (LWEC) programme, which aims to "provide decision makers with the best information to manage effectively and protect vital ecosystem services on the time and space scales on which the economy is managed". Valuation is implicit in most of this programme's objectives, and explicitly in Objective B which sets out "to assess the links and feedbacks between the natural environments, ecosystem services and human well-being". In this respect LWEC seeks to determine how improvements in social welfare could be sustained "within environmental limits in the face of major environmental change". The LWEC initiative also seeks to support decision-makers at a local and national scale as they seek, not only to manage the constraints imposed by available natural resources, but also take up "new social, environmental and economic opportunities".

In this respect, there is an irrefutable case for integrating natural and social sciences in order both to inform and respond to societal values for the diverse range of goods and services provided by natural resources (Denham, 2009). The science of valuation can make a major contribution to understanding the complex relationship between environment, society and economy.

1.2 Purpose and Aim

In this context, the broad purpose of this scoping study is to help inform NERC strategies on the valuation of NRES as part of its themes on the sustainable use of natural resources, thereby enhancing NERC's potential contribution to achieving sustainable development in practice.

The study aims to produce a 'state of the science' review of valuation in terms of what exists, what is being done, how well it works and likely future needs.

1.3 Objectives

The review has the following objectives, framed in terms of questions to be addressed:

- What are the main types and applications of valuation research with respect to NRES?
- What is the perceived capacity and quality of output in NRES valuation?
- What are the main challenges with respect to data, methods, and expertise?
- Who is interested in NRES valuation and how is it used?
- What are the priorities for NERC regarding NRES valuation?

Throughout the process, the specific implications for NERC's role as a provider of new knowledge are explored, especially regarding the integration of natural and social sciences.

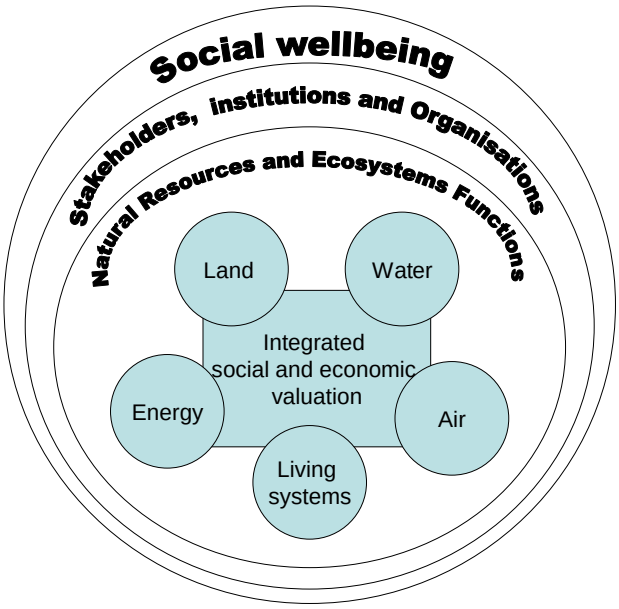


Figure 1.1. Conceptual Framework for NRES Valuation Research

1.4 Conceptual Framework

Figure 1.1 contains a conceptual framework that defines the focus and boundary of the scoping study with respect to the valuation of NRES. The figure conceptualises the two way relationship between social welfare and the use of natural resources. The purpose of valuation is to assess the type, magnitude and significance of this relationship, and how changes in one can affect changes in the other.

Figure 1.1 contains three interacting spheres of influence. Aggregate social well-being is the outer sphere and, as explained below, is the purpose of the NRES system. This captures the concept of sustainable development. It comprises an amalgam of social, economic and environmental outcomes that represents well-being, defined at the relevant scale.

At the intermediate level, stakeholders pursue their various interests through a variety of institutional and organisational structures and processes. They exert influences over NRES through an array of entitlements, formal and informal. The outcomes of these stakeholder activities contribute to the sum of societal welfare.

At the core of the framework, natural resources and the associated functions of naturally occurring ecosystems bestow benefits to stakeholders in terms of the services they provide (referred to as ecosystem services as explained below). In particular, these functions and services relate to land (and soils), water, air, energy in various forms and living systems.

The system perspective contained in Figure 1.1 emphasises anthropogenic interests – the purpose of the system is to support and enhance social welfare. The term natural 'resources' reflects a utilitarian, instrumentalist viewpoint, where resources are valuable because they are useful and add value. Simultaneously, and by definition they are, from a human welfare perspective, limiting in some way. Resources which are not limiting are redundant and have no utilitarian value at the margin. They may have other values of course associated with non- and intrinsic worth, including in the case of living systems their own inherent right to exist. Furthermore, the value of natural resources and related functions may be hidden by the complexities of biological and physical processes. And given the dynamics of natural systems and human needs, present perceptions of limits and value may be at odds with those that emerge over time.

The challenge represented in Figure 1.1 is to understand the two-way relationship between changes in the status and use of natural resources and changes in social welfare. Essentially, this concerns the Sustainable Use of Natural Resources, one of NERC strategic science themes. Specifically for this scoping exercise, the challenge is to explore the extent to which current knowledge, evidence and techniques of valuation are sufficient to understand this interrelation, and what actions, if any, could be taken to enhance this understanding with a view to sustaining improvements in social welfare.

The conceptual framework in Figure 1.1 also has important implications for the choices of private individuals and organisations, and of communities and nations as they seek to enhance their welfare. The use of natural resources is a major domain for governance and policy as these seek to deliver sustainable development. As a national research council, NERC science is required to be relevant to policy needs, especially of a long-term strategic nature. In this respect, NERC science should inform the relationship between changes in NRES and social welfare, guiding policy and decision making in the process. This is a valid reason for NERC science to engage in the valuation of environmental change. The questions are - in what way, to what extent and who should be involved?

Chapter 2 : Methodology

This section explains the methods used to address the study objectives.

Key messages

- A variety of methods were used to assess the current state of valuation with respect to NRES, these included a search of academic literature, email questionnaires, and semi-structured interviews.
- NRES valuation subject matter is wide ranging and growing. Inevitable inconsistency in the classification of subject matter and key word descriptors makes literature search particularly challenging.
- A number of dedicated web-based research inventories and project sites were reviewed that facilitate information and knowledge exchange on NRES valuation, including data, methods and results.
- An email survey of 150 researchers involved in NRES valuation, followed up by telephone interviews in some cases, yielded a 20% response rate. Results from this were stored electronically to enable systematic retrieval.
- A formal review of the treatment of risk and uncertainty in NRES valuation research was not possible within the resources available. This was a topic identified for further work, including the development of practitioner guidance.
- Organisational review and Stakeholder analysis showed a diverse range of interest in NRES research.

2.1 Survey of Approaches to Valuation

A review was carried out of current approaches to valuation of NRES. This involved a number of components, as follows.

(i) A review of existing inventories of literature on natural resources.

The Environmental Valuation Reference Inventory (EVRI) is major inventory, which is the produce of a joint project between various organisations in various countries, including Defra in the UK. EVRI is a benefits transfer database and is intended for use by policy makers and researchers. The assumption behind the benefits transfer approach is that valuation data from a "study" site can be transferred and used at a "policy" site, if both study and policy sites are sufficiently similar and appropriate adjustments are made to the transfer values. A similar database is ENVALUE developed by the Department for Environment and Climate Change in New South Wales, Australia. The structure and classification scheme from EVRI and ENVALUE contributed to the development of the questionnaire that was later sent to valuation researchers. A brief summary of the EVRI Inventory is provided.

(ii) A broad review of the literature in the Centre for Agricultural Bioscience International CAB Abstracts

According to CABI, "CAB Abstracts is the most comprehensive bibliographic, abstracting and indexing database in the applied life sciences". It reviews research from more than 150 countries in over 50 languages, which was considered to be useful as the scoping study aimed to include international valuation research. Since 1973, it has indexed more than 5.2 million records from over 7,000 journals and over 3,500 serials, books, book chapters, conference proceedings, and grey literature. It is used by hundreds of Universities around the world and was used by the FAO AGORA project, which aimed to provide access to research literature in developing countries.

A search of the recorded literature using a key word search in the database was undertaken. This involved downloading over 5,000 records that were recorded in the CAB Abstracts as having a subject heading of "valuation", "contingent valuation", "willingness to pay" and "non-market benefits", since it was thought that these would include much of the literature on valuation. The subsequent references were sorted into a relational format. However, it was evident that some of these references were at most, peripherally related to the topic of valuation. In order to refine the records selected, a series of key words were used to select references that included at least the name of a specific resource and an economic or social approach to valuation. This reduced the Inventory to approximately 3,200 records. Clearly, a more detailed review of these records would have provided another layer of refinement to the selection process. However, given the resources available, the adopted procedure, although not perfect, provided an approximate and broad-brush view of the literature. It also provides an excellent way of quickly filtering through to a small subset of natural resources valuation literature. A ranking of the frequency with which individual authors and institutions were cited in this selection of references was used to identify researchers for the questionnaire and stakeholder organisations for the stakeholder analysis. The references are currently assembled in a spreadsheet, supported by annotated classification.

(iii) A focussed review of selected most cited literature using WEB of Science

Web of Science was used to find a selection of 'exemplar' valuation research across a variety of subject areas. Particular attention was given to the most cited publications, over a range of dates, old and more recent, including those extremely influential in terms of the current state of science. It was found that many highly cited valuation research originates in the USA, but for the purpose of this study, research from the UK and Europe has been included that has fewer citations, but is indicative of relevant authors, institutions and research areas. It should be noted that it is not clear whether these papers have been highly cited because of the subject matter such as wetlands, biodiversity, energy, or because they are considered 'exemplar' or influential in terms of valuation techniques used.

(iv) A detailed questionnaire sent to 150 researchers.

A detailed questionnaire was developed in Excel and sent by email to approximately 150 UK, European and International researchers who had been identified through as key authors in valuation research. These were identified through personal contacts, through the Inventory databases as frequent publishers of valuation research, and as part of the research effort in valuation through their association with University departments and valuation projects which were searched through their websites. The questionnaire was divided into two parts. The first asked general questions about the respondent's research, focussing on generic issues such as their experience with valuation and decision support methods, the stakeholders funding their research and with whom they interact, and their thoughts on the suitability of the data used, the outputs generated and future priorities for valuation research. The second part sought information on key research outputs. The type of information collected is shown in Box 1 (The full questionnaire is contained in Appendix B). Content-analysis data retrieval procedures were used to extract information according to key themes.

Box 1. Type of information collected by email questionnaire survey

- Broad topic area of research: e.g. Land, Air, Water, Living Organisms, Energy and functional focus (e.g. production, regulation, habitat, cultural).
- Choice of indicators and focus of valuation, (e.g. economic, social, or environmental), and the extent of integration of these indicators.
- Valuation methods used and suitability of valuation methods (e.g. income/cost based methods such as dose response and defensive expenditure; expressed/revealed preference methods such as contingent valuation, choice experiments, participatory scoring/ weighting/ ranking, gaming, and visualisation methods; network and panel approaches, expert panels, delphi, and citizens juries).
- Decision support methods used, suitability of decision support methods used (e.g. cost-benefit, cost effectiveness, multi-criteria, risk based assessments, programming and simulation, econometric (regression based) methods, life cycle analysis, environmental accounting, Bayesian simulation, neural networks, collective choice methods).
- Context and stakeholder characteristics (e.g. dominant stakeholder groups, sectoral development/remediation, protectionist/conservationist, policy/regulatory context, property right regimes).
- Key data and assumptions (e.g. assessment of suitability, quality, robustness, management of uncertainty in data and methods).
- Contribution and use (e.g. end-user orientation, usefulness, applicability, relevance, including links to decision support).
- Consideration of future priorities for valuation research and role of valuation research in future policy and decision-making

Twenty four completed questionnaires were returned, mostly from the UK. A number of other respondents said they would prefer to respond without completing the questionnaire because of time constraints and these were subsequently contacted using the shorter e-mail questionnaire and by telephone interviews.

(v) A short follow-up questionnaire to those who did not respond to the detailed questionnaire

A short questionnaire in an e-mail with nine open ended questions was sent to respondents who did not reply to the detailed questionnaire, or expressed a willingness to respond to a shorter set of questions in a different format. This covered similar ground to the generic issues of the detailed questionnaire. Respondents were invited to attach papers or electronic resources to their reply. This produced about ten additional responses, again from UK researchers.

(vi) Telephone interviews with ten selected respondents previously identified.

These interviews focused on providing an understanding of the purpose and context of the type of valuation studies carried out, the main challenges associated with valuation, notably regarding data, methods and integration of scientific viewpoints. The interviews also explored perceived priorities for future research to support valuation, as well as perceptions of the role of NERC funded science. These interviews each took about 40 minutes.

(vii) A review of valuation projects conducted by sponsoring agencies

This included research councils, Government Departments and the European Commission projects. This included projects such as CASEBASE[4], ENVALUE and EVRI that aim to provide inventories of cases studies and values, these are projects that aim to promote the valuation of environmental services through information provision, including the mapping of ecosystems services and to provide novel computer tools for decision-making. Such projects include the EU TEEB project and the Natural Capital Project.

2.2 Assessment of Validity and Robustness of Valuation and Sources of Uncertainty

During the questionnaire surveys and interviews, attempts were made to identify sources, magnitude and significance of risk and uncertainty in valuation studies. Particular attention was paid to obtaining respondents perceptions of their estimates in the appropriateness, quality, and uncertainties in the collection and use of data and in the application of valuation methods. Attempts were made to determine uncertainties arising from: (i) the suitability of selected 'indicators of valuation' in given contexts, (ii) data type, sources and collection methods, (iii) scale of analysis and degree of aggregation, including data from secondary sources, targeted surveys, and data 'transferred' from one application to another, (iv) key assumptions and conditions associated with analytical methods (v) recognition and treatment of variation and uncertainty by means of probability and sensitivity analysis, (vi) potential usefulness/applicability of valuation for decision-making.

Discussions were held with respondents about how uncertainty has been, or can be assessed, managed and communicated. It was intended to create a 'valuation risk rule' that combines an assessment inherent risk in valuation methods for particular NR applications, together with an assessment of actions to manage these risks. This proved infeasible in the circumstances, although the enquiries here confirm the need for such an approach. This item is carried forward as a recommendation for (i) guidance on the execution of valuation studies and (ii) procedures for the evaluation of completed studies.

2.3 Review of Work carried out by Organisations and Individuals

Key work carried out by organisations and individuals in the NRES field, both within the UK and internationally, was indentified as part of the review exercise referred to above. This review indentified where NERC science and scientists could contribute and/or collaborate. This review classified organisational involvement by (i) range/scope of NR sectors such as land, water, air, energy, and biosystems, such as fisheries and forestry, environmental risk, including climate change, (ii) types of valuation studies and techniques (iii) scale of study (iv) organisational types (iv) and roles whether research providers, brokers and end-users, including key applications in practice.

2.4 Synthesis of Stakeholder Involvement

Drawing on the above, stakeholders with interest in, and influence over NRES research were identified. For this purpose, a stakeholder mapping tool was used to link stakeholder interest and influence with particular elements of NRES. An annotated inventory of stakeholder interests was developed, informed by the review process.

[4] Nature Valuation and Financing Network: http://topshare.wur.nl/naturevaluation

2.5 Implications for NERC SUNR Themes and possible Future Engagement in NRES Valuation

Discussions with key informants explored priorities for NERC science with respect to NRES valuation. Discussions were also held concerning the perceived suitability of alternative approaches to NERC engagement in this area of research, especially drawing on the practical experiences of researchers.

Chapter 3 : Defining NRES Valuation

This chapter defines the boundary of the study topic with respect to the valuation of Natural Resources and related Ecosystem Services (NRES). The concept of valuation is briefly reviewed, followed by that of NRES and the use of the ecosystems framework. The inherent uncertainties of ecosystems are briefly reviewed as they affect valuation, together with a review of relevant valuation methods.

Key messages

- From a human perspective, the term value implies something that is good and pleasurable. This view of value is largely 'instrumental' in that something is good because of the benefits it bestows.
- Natural Resources, including land, water, air and associated living systems, are valuable because they can provide a flow of beneficial goods and services which add to the sum of social welfare.
- The concept of ecosystem functions and services captures the diversity of flows of services and provides a framework for valuation, recognising value in use and non-use.
- Stakeholders extract value from the use of ecosystem services, exercising influence through property rights and entitlements.
- Many of the benefits of natural Resources and related Ecosystem Services (NRES) take the form of non-market, public goods whose values are difficult to directly ascertain.
- Making judgements about the value of NRES is made difficult by inherent uncertainties associated with the response of ecosystems to anthropogenic pressures, giving rise to either gradual or catastrophic failure, with consequences for human welfare.
- A range of techniques are available for the valuation of NRES, involving economic methods to derive monetary values and deliberative/participatory methods which seek to elicit values and preferences for environmental goods and services through discourse and knowledge exchange.
- Deliberative methods have partly been developed in an attempt to overcome the perceived limitations of economic valuation methods.
- There is scope, within an ecosystems framework to combine these different methods to good effect.

3.1 Concepts of Valuation

From a human perspective, the term value implies something that is good and pleasurable. In the classical economic sense, value is associated with utility, satisfaction, happiness and the avoidance of pain. It is assumed that people take actions in pursuit of pleasurable outcomes, judged against some set of consistently applied criteria used to assess relative value of outcomes for the individual. Thus, notions of utility and the set of values on which it is based vary amongst people for a whole variety of reasons. The utility of a given outcome may also vary for any one person over time and space because of changing circumstances, such as wealth, health or access to alternatives.

This view of value is largely 'instrumental' in that something is worthwhile, not for its own sake, but because of the benefits it provides to those who possess, control or use it in some way. Items also can have 'intrinsic' value in themselves, for their own sake, independent of any human perception of value, such as, for example, marine ecosystems. These 'intrinsic'

values, however, sometimes shape a moral obligation felt by humans to protect other living systems and their habitats from damage or extinction. In this case, intrinsic and instrumental values are difficult to disentangle. Satisfaction gained by adopting a moral position can infer instrumental value.

Taking an instrumentalist viewpoint, value reflects usefulness, further indicating that something is fit for purpose and in someway facilitates beneficial outcomes. Value is also associated with concepts of scarcity. Resources, or items of consumption, which are abundant have zero value at the margin – users are completely satiated and further consumption adds no further benefit, and may actually reduce total utility. In this respect, economists tend to express value in terms of equivalent value of consumption, conveniently expressed in terms of income, and hence willingness to pay a price to obtain a benefit.

Thus, to some extent willingness to pay provides a measure of extra utility. This is consistent with the notion of opportunity cost, denoting a willingness to give up one thing to obtain another preferred item. Thus prices paid and received in the market place provide an indication of value, at least at the margin of consumption. Market prices of goods and services are the most commonly used signal of value for comparison and exchange, and for resource scarcity (Costanza *et al.* 1989; Clarke & Joosten 2002; Brauer 2003). Markets are most effective where there are large numbers of buyers and sellers and there are clear, enforceable and transferable property rights. Under these circumstances, in theory, prices direct the allocation of scarce resources to their most efficient use, thereby maximising overall societal welfare (Costanza *et al*. 1989; Hanley *et al.* 2001; Tietenberg 2003). It also must be remembered that market prices and hence price based values, are a product of prevailing income levels and distribution. Change these, and values may change absolutely and/or relatively.

Unfortunately, however, these market conditions do not apply consistently to NRES, especially, as discussed below, to those generating 'use' values which are not traded in the market place, and even more so for those associated with 'non-use' benefits. Furthermore, many of these benefits are not captured within the dominant system of entitlements and property rights which define market transactions and hence values. Loss of eco-system functions often manifest themselves as external costs, lying outside the property rights that are the subject of a transaction. This represents a failure of the market system and poses a major institutional challenge.

Even where markets are operating efficiently, prevailing prices underestimate the total value of consumption because many consumers/users would have been willing to pay higher prices than they needed to. In other words, they derive 'consumer surplus', that is benefits over and above the price actually paid. Indeed, where environmental services are enjoyed in the form of non-market 'free' public goods, the entirety of value is made up of consumer surplus. Market prices are thus not a complete indicator of value for environmental goods and services, even when they are commoditised and marketed in some way, as with fishing permits.

Nevertheless, as discussed below, significant progress has been made on the valuation and inclusion of ecosystem functions in decision making, but estimates need to be treated with caution (Brouwer *et al.* 1999) and regarded as indicators of relative value rather than absolute value (Garrod & Willis 1999; Turner *et al.* 2003).

From an economics perspective, dealing with issues of valuation and the efficiency of market systems comes under the heading of welfare economics. Here the purpose is to determine

how the allocation of resources can maximise total social welfare. Although the consumption of goods and services is expediently used to measure welfare, it is widely accepted that consumption alone is not a reliable and complete indicator of well-being and value. Many other things, evident in measures such as the UN Human Development Index, The Millennium Ecosystems Assessment measures of social well-being, and the UK Government Sustainability Indicators, are critical elements of welfare.

For these reasons, more attention has been given recently to measures of value that are independent of consumption and market factors. Developments in psychology, anthropology, neuro-science, combined with behavioural economics which is not predicated on a consumption-based view of utility, are providing new insights into environmental valuation. These seek to provide a better understanding of how values are constructed and how values change in response to changing circumstances and external factors, such as perceptions of threat or opportunity, how values vary with knowledge and experience, and how they are constructed by individuals alone or groups working collectively.

In recognition of the need for broader definitions of value, utility and welfare, there is greater interest, both in the research and policy arenas, of developing diverse measures of outcome that go beyond conventional economic measures. In the UK for example, these are apparent in the Public Sector Agreements on habitat creation, protection from flooding, and water quality. In such instances, economic assessment is largely confined to delivering outcomes most cost effectively.

3.2 Natural Resources: stocks and flows

Resources are valuable in that they are useful and 'add-value' in systems of production and consumption. Resources are used as long as the value derived from their use exceeds the costs of use. In theory, distinction is made between the 'total value' of resources in use and 'marginal value' which is the value added by the last unit of a resource that is used. In the theory of market economy, if resources are unlimited, they will be used up to the point where the value-added by the last unit of resource employed is zero. If they are limited in supply, marginal value will be positive. Resources are employed in a range of economic activities. In theory again, resources will be drawn to those uses in which it adds most value, responding to prices offered in resource markets, until that is prices for specific resources are the same in all applications, and no further reallocation can enhance total added-value. This is a theoretical optimum resource allocation

Natural Resources include land, water, air and associated living systems comprise the mineral, plant and animal component of the biosphere, organised into ecological systems or ecosystems (Hawken *et al.*, 1997). They are 'natural' in so much as they are the product of physical, chemical and biological processes over different time and spatial scales that are potentially independent of human interference. From an anthropogenic perspective they are 'resources' in so much as they can be used, along with other types of resources (financial, physical, human, social), to produce goods and services that are of value to people. The demand for resources is thus indirect, driven by the demand for final consumption.

Natural resources are often referred to as natural capital and can be considered as a stock of capital or assets of given quantities and qualities. The present value of a stock of resources is some measure of the future flows of benefits that it can generate over its lifetime, until it is used up. Some natural resources, such as fisheries and forestry, biologically regenerate such that 'harvesting' can be managed at rates which do not reduce the overall stock. Indeed a condition for sustainability is to maintain the stock of natural resources over time, although

some types of non-renewable resources may need replacement by other forms of capital as they are depleted.

Some of the flows of benefits from the use of natural resources, such as land for agriculture and oil for power generation, are obvious and commonly traded in the market place, commanding prices that reflect their value in use. Many flows of benefits from natural resources are non-market, un-priced goods and services which are enjoyed as public rather than private goods. Problems arise, mostly associated with failures of governance, when these beneficial yet often hidden flows of services are lost due to over use or damage, with consequences for human welfare. The impacts of climate change and overfishing for example are largely due to over-exploitation and degradation of natural resource stocks.

3.3 Ecosystems Functions, Services and Values

For the reasons given above, it is important, therefore, that the contribution to human welfare of natural resources and the services that emanate from them are properly recognised and valued, and measures taken to protect their future integrity. In this context, the concept of ecosystems functions and services has emerged as a means of explicitly linking natural capital with social welfare.

Figure 3.1 summarises the ecosystems paradigm. Natural capital supports a number of interrelated ecosystem functions (production, regulating, habitat, carrier, and information functions) to provide capacity to produce a variety of ecosystem goods and services that have value for humans (de Groot, 2002). A measure of Total Economic Value (TEV) can be derived by combining use- and non-use values (Pearce and Turner, 1990).

Use value is divided into direct-use value and indirect-use value. Direct-use value may be consumptive (e.g. fishing and hunting), extractive (e.g. timber logging), or non-consumptive (e.g. recreational and educational). Indirect-use values may involve interaction with the ecosystem via the services provided, and includes removal of nutrients, water purification, flooding and disease control. Non-use value is derived from knowledge that the ecosystem and its services exist and are maintained now and for future generations.

In this respect, non-use values do not involve direct interaction between humans and the ecosystem itself, although in-practice non-use may be deliberative and may involve actions to protect and preserve Non-use values include existence value, bequest value, altruistic value, and option value. Existence value stems from the satisfaction that humans derive from knowing that a particular ecosystem exists. Bequest value is associated with the knowledge that the ecosystem and its services will be passed to future generations. Altruistic value derives from knowledge of the fact that others may enjoy the goods and services of a particular ecosystem. Option value refers to benefit from the security of knowing that an ecosystem is being preserved for possible future use (or non-use).

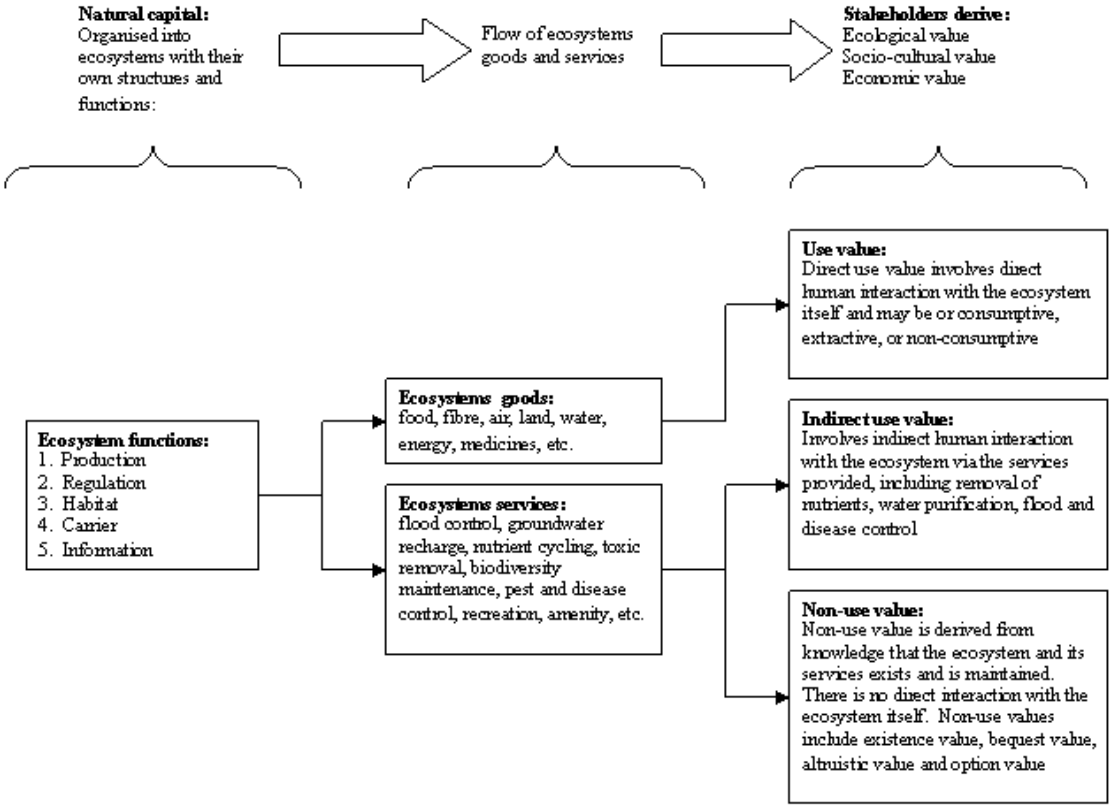


Figure 3.1. The ecosystems approach shows the relationship between natural capital, ecosystem functions, services and stakeholder values (developed from Hawken *et al*., 1997; Turner, 2000; de Groot *et al*, 2002, 2006; Newcome *et al*., 2005)

3.4 NRES Values and Stakeholders

The ecosystem framework makes the explicit link between flows of goods and services and stakeholder values, covering a range of ecological, socio-cultural and economic dimensions (Orr *et al*., 2008). . Stakeholders here are individuals, groups or organisations with an interest in, and who derive potential benefit or loss from a change in ecosystem services. They might also be distinguished according to the degree to which they can influence service flows, using through the entitlements and the control of resources (Turner *et al.,* 2000; Reed *et al*., 2009). Balancing the requirements of all stakeholders while, where possible, maintaining the integrity of the ecosystem requires a sound understanding of existing social, economic and environmental interactions (Ravnborg & Westermann 2002). Stakeholder participation and analysis is a key element of NRES valuation.

3.5 NRES Values and Property Rights

The ecosystems approach emphasises the importance of stakeholder 'property rights'. These are bundles of claims or entitlements to a stream of benefit usually associated with the use of resources, including natural resources such as land and water. Thus, the relationships between people and natural resources are configured by an array of norms, conventions, legal rules and regulations (North, 1990; Schmid, 2004). These socially constructed institutions confer

property rights to people, as individuals, groups or organisations, which enable them to derive value from the use of natural resources.

Critically, a single natural resource may deliver an array of beneficial services, the rights to which may be vested with more than one individual stakeholder (Bromley 1991; Baltzer 1998; Adger and Luttrall 2000). The failure of property regimes to include the 'external' effects of transactions involving the use of natural resources, whether positive or negative, is a failure to value the complete range of ecosystems services. This has consequences for social and ecological welfare Indeed, over-exploitation of ecological reserves beyond regenerative capacity eventually threatens the viability of the production systems and the human populations that depend on them (MA, 2005).

It is important to note that 'entitlements to benefit' are not absolute, but rather derived in accordance with dominant societal preferences and priorities, and these vary spatially and temporarily (Tawney, 1948; Bromley, 1989). There are two key aspects of property rights, namely: the subject of the entitlement, (i.e. the benefit) and the regime (i.e. whether private, state, common or open access). Historically, property regimes have given precedence to production functions, such as farming and fishing, evident for example in the award of agricultural land tenure or riparian fishing rights (Bromley and Hodge, 1990; Hodge, 2001). As a consequence the value of land is measured in terms of the rents (profits) derived from agricultural use and outputs. Impacts on other functional interests associated with the public good such as hydrological regulation, natural habitat and cultural quality may be excluded from the decisions of 'profit-seeking' producers, as these can be passed on to third parties without compensation or payment (Turner, 2001; de Groot, 2006).

The tensions that arise between different stakeholder interests in respect of NRES may call for changes in the institutional arrangements that govern entitlement to property rights. This means that scientists need to engage within governance systems, rather than as is often the case, working independently of them. It may require, for example, using research outputs on the dynamics and values of ecosystem services to challenge policy makers who operate within separate established frameworks (Carpenter and Folke, 2006; Hindmarch *et al*, 2006).

3.6 Millennium Ecosystem Assessment

Interest in the ecosystems approach was stimulated by the Millennium Ecosystem Assessment (MA). This conceptualises the relationship between ecosystems, the services they provide and the benefit in terms of 'constituents of well-being' (Figure 3.2). The MA also set out to document the current status of ecosystems goods and services at the global scale and to identify future risk to which they may be subjected. The MA, drawing on peer reviewed evidence, has gained wide international support such that the conceptual approach and the results have considerable authority. The explicit link between ecosystems services and well-being provides a framework for valuations. However, the enumeration of service types is not complete because of a lack of data and the approach is more suited to broad rather than detailed and locally relevant appraisal of policy and development options. For this reason the approach, outlined in Figure 3 is considered more appropriate as a practical framework for NRES valuation.

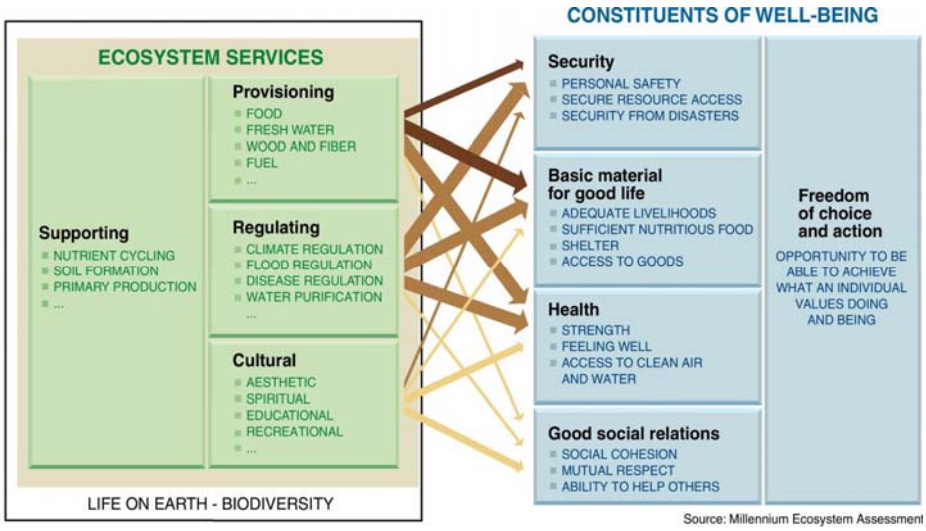


Figure 3.2. The Millennium Ecosystem Assessment Shows the Links between Ecosystems and Social Well-being

3.7 Assessing Ecosystem Risks: Pressure and Tipping Points

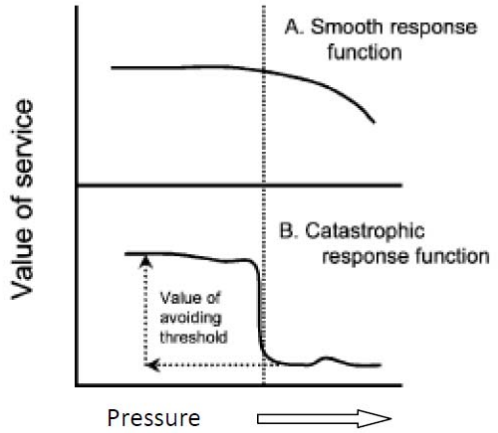
It is important that valuation of NRES allows for the inherent risk and uncertainty of ecosystems as they exhibit complex dynamics, involving nonlinearities, thresholds and discontinuities, as well as more gradual changes to external pressures (Holling, 2001).

As a result, management or policy interventions in such systems may be difficult, and can involve making decisions against a backdrop of considerable uncertainty. Sudden regime shifts are often hard to predict or anticipate, and large disturbances may cause a rapid change in ecosystem structure and function whereas previously the system appeared to be fairly resilient to change (Scheffer *et al*., 2001; Scheffer *et al*., 2003; Scheffer and Carpenter, 2003; Walker and Meyers, 2004). In the context of the present study, the existence of such behaviour is particularly significant because it then becomes difficult to estimate how the value of a resource may change in response to different levels of demand or external disturbance.

As this study shows, a range of methodologies are available to value changes in ecosystem services. Generally these values are considered in relation to the Total Economic Value (TEV) framework referred to above that takes into account the use and non-use values individuals and society gain or lose from *marginal* changes in ecosystem services (Defra, 2007). As mentioned above, the concept of marginal change is used to express the value that attaches to an extra unit of the service, when all other factors are held constant. It is useful to calculate because it allows one to compare the benefits that a consumer would derive from a given ecosystem good or service, against the benefits that might arise from some other expenditure, or with situations in which the structure of that ecosystem is modified and output levels change.

As Limberg *et al*. (2002) has pointed out, however, if the valuation process is fundamentally about "the 'difference' something makes", then analysis of marginal value is *only* possible when an ecosystem is far from an unstable threshold. Thus they identify what they call a 'marginal regime', in which there is high degree of certainty and predictability in understanding the relationships between the different parts of the ecosystem (Figure 3.3, A).

In these situations individuals are well placed to make decisions about trade-offs and substitutions and marginal values can be obtained from the analysis of people's preferences. Close to an unstable threshold, however, other criteria appear to apply. In these situations (Figure 3.3, B) we face what Limberg *et al*. (2002) call a 'non-marginal regime', where the assumptions needed to calculate the marginal economic value are longer valid. The criteria used to make judgements about the gains and losses resulting from small disturbances under the predictable conditions of the marginal regime, cannot easily be made, because disturbances of the same magnitude can trigger potentially catastrophic events.



Situation A represents the 'marginal regime' where the differences value due to increasing stress can be valued in monetary terms; situation B is the 'non-marginal regime'

Figure 3.3. The impact on environmental pressures on the value of an environmental service

When faced with collapse of an ecosystem Limberg *et al*. (2002) suggests that questions of trade-offs and substitution of benefits that are associated with marginal valuations, no longer apply. Thresholds can cause the value of a resource to fall sharply once a certain amount has been used. As situation B in Figure 3.3 illustrates and understanding of marginal changes before the point of collapse is reached in no way allows one to predict the value of avoiding this tipping point.

The distinction that Limberg *et al*. (2002) make between these marginal and non-marginal regimes reflects a much wider debate between the environmental economists on the one hand and ecological economists on the other (cf. Pearce, 1998). While the former argue that economic valuation is possible and essential in all situations, the latter hold that in some contexts, particularly those where these unstable threshold regions exist, such economic valuation is not always applicable or at least not the only criteria that may be applied. It is often argued that in situations where marginal economic valuation is not appropriate, other types of valuation, such as social and ecological are claimed to be more useful. Ecological values emphasise properties such as resilience and ecosystem integrity, or environmental space, and equate more strongly with notions of the values associated with risk avoidance (cf. Deutsch *et al*., 2003; de Groot *et al*., 2003; Spangenberg, 2002). Risk avoidance also corresponds to applying the types of ethical criteria emphasised by those who advocate social

valuation, since questions of rights and environmental justice may arise if the loss or collapse of ecosystem function impinges on human health or welfare (Bührs, 2004).

It is important to note that the distinction between marginal and non-marginal regimes does not imply that ecological and social criteria are *only* applicable in situations where catastrophic collapse is threatened. Rather, it is suggested, that in these situations economic valuation is more difficult and so these other types of consideration are likely to be more dominant. However, by no means all agree with Limberg's *et al*. (2002) proposition of marginal and non-marginal regimes. Pearce (2004) has, for example, provided a powerful critique of key elements of the position taken by ecological economics, and has cautioned about the dangers of 'building a science on limited rather than general ecological behaviour' (Pearce, 2002, p43). For him, economic valuation is applicable under all circumstances. Conversely, in these circumstances where ecological economists argue that ecological and social value is more applicable, then a range of participatory or discourse–based methods, such as citizens' juries, probabilistic risk analysis, multi-criteria decision analysis and scenario planning are appropriate (Chee, 2004; de Groot *et al*., 2003; Hein *et al*., 2006; Peterson *et al*., 2003; Wilson and Howarth, 2002), as discussed below. Clearly these kinds of approaches need to sit alongside the other methods proposed for the analysis of TEV and that robust valuation will increasingly have to draw upon a range of different approaches, particularly where issues are explored against the backdrop of climate change. In terms of the kinds of underpinning science that bodies such as NERC need to provide, an understanding of the complex dynamics of natural resource systems is essential if these different valuation methodologies are to be used appropriately.

3.8 NRES Valuation Techniques

There is a range of valuation methods that can be used to measure changes in NRES, broadly classified into two groups, economic and deliberative/participatory methods (Eftec, 2006).

3.8.1 Economic valuation

With respect to economic valuation methods, where environmental goods and services are traded in the market place, such as entrances charges to a national park, market prices can be used to give an indication of value and the change in consumer surplus (as referred to above).

Where environmental goods and services are not traded in the market place, two broad categories of methods can be used depending on the characteristics of the environmental change and the type of benefit to be assessed.

Cost and Income based measures attempt to estimate the value of an environmental change through its effect on income or costs using market or related proxy prices. These include dose response, earnings loss, defensive or mitigation expenditure, replacement costs or substitute goods, and shadow (alternative) project investment.

Demand based measures attempt to estimate willingness to pay or accept compensation for an environmental change. These demand based methods measure the change in consumer surplus, as explained earlier, and hence a measure of welfare change. They comprise two main types, revealed preference whereby actual behaviour and willingness to pay provides the estimate of value, and stated preference whereby respondents are asked to express a willingness to pay in order to gain or avoid constructed, hypothetical but potentially real environmental options. In the form of choice modelling, the methods present respondents

with a range of environmental attributes amongst which they are asked to express a preference and/or a willingness to pay.

These methods are suited to estimating different types of environmental benefits. User benefits can be assessed with a range of market proxy and demand based (stated and revealed preference) methods. Valuation of non use benefits can only be assessed using stated preference methods.

Since collecting economic valuation data is expensive and time-consuming, a more recent development has been to collect data on social preferences and compile them in databases or accounting systems, for use in research and policy-making. In this way, data derived from a "study site" is transferred for use at a "policy site" so that they can be used in equivalent circumstances, a process termed 'benefits transfer' (Defra, 2007). The derivation of initial benefit estimates, which explain demand in terms of constituent influencing factors, such as particular characteristics of the beneficiary population or the local availability of substitute service, facilitates greater precision in benefit transfer.

3.8.2 Deliberative and Participatory Methods

Deliberative and participatory methods attempt to elicit preferences for environmental goods and services through some form of discourse and exchange. These include unstructured interviews, focus groups, panels, citizens juries, discussion fora, learning schools, away days and 'walk abouts' (sondeos), game playing, and various forms of interactive visualisation.

Deliberative methods attempt to determine why individuals behave in particular ways or hold particular perspectives. Such approaches attempt to understand the process of decision-making itself, and to determine what individuals think are the appropriate actions for the achievement of social justice. In this respect, deliberative and participatory methods are different from economic methods in so much as they attempt to consider the moral dimension of those preferences. A further difference is that, whereas economic methods tend to "treat preferences as pre-existing and stable constructs", deliberative and participatory methods tend to consider that "preferences about complex environmental matters are only formed through deliberation". Many of the methods involve the knowledge exchange between all participants, including 'experts' providing information in response to perceived need to know.

A listing of methods is given in Table 3.1 (More details are in Appendix D). In addition, a more detailed commentary on non-monetary valuation methods is included in Appendix E.

Table 3.1. Methods for the derivation of environmental values

Economic methods
Market price proxies use the prices that can be observed in markets to value environmental goods and services,
Production function methods rely on determination of the relationship between ecosystem goods and service and a marketed product and are used to capture indirect use value
Hedonic pricing uses the prices of traded commodities to determine the value of environmental characteristics that are thought to affect the price of the item. .
Travel cost uses costs, such as travel costs, entrance fees and time, incurred in visiting a particular site for recreation or other purposes as a proxy of the value of that site for the purpose.
Contingent valuation is a survey-based approach that constructs hypothetical markets to determine individual willingness to pay for environmental goods and services using a questionnaire.
Choice experiments/ modelling assess the extent to which preferences and willingness to pay are influenced by the level of attributes of environmental goods and services.
Random utility models are a subset of choice modelling that considers the variability of factors influencing values and preferences.
Deliberative and participatory methods
Personal survey approaches involve unstructured interviews can could be used to explore respondent views about environmental valued.
Focus groups bring together to jointly discuss and possibly rank preferences on issues of environmental change.
Citizen's juries involve groups of representative citizens that reach a judgement about a particular environmental option.
Health-based methods measure the impact of an alteration to the flow of ecosystem goods and services on health, in terms of quality of life and life expectancy, sometimes linked to income lost.
Q-methodology is a survey-based approach that attempts to understand how patterns of values and perceptions on the environment that are shared.
Delphi survey and systematic reviews involve the derivation of successive rounds of expert opinion on particular environmental goods and services.

3.9 Integrating Valuation Methods

Differences between economic and deliberative are not necessarily incompatible and indeed merging them in valuation research is considered beneficial (Eftec, 2006), a point that was reinforced during our survey of researchers. For both approaches, it is important to consider that the way in which ecosystem goods and services are affected by particular actions is not always well understood. As discussed above, if basic scientific understanding is known to be flawed or limited, then it is important to account for this uncertainty in the derivation of values, perhaps by considering alternative scenarios.

Since respondents in valuation research can only express preferences in so far as their knowledge allows them to, it is important to provide the appropriate information to participants so that they can make informed decisions. For example, few people are aware of the importance of soil fauna and their values and preferences are likely to reflect this. It might, however, be the case that their lack of awareness means that they do not value soils directly, but rather rely on others who are closer to soils, such as farmers producing crops, to

adequately capture values, indirectly passing environmental values on to consumers through farm commodity prices.

3.10 Assessing the quality of valuation research

In response to the increasing importance of the reliability of valuation results for use in a policy context, Söderqvist and Soutukorva (2009) have attempted to construct a "practicable quality assessment instrument (QAI)". They developed a definition of 'quality' based on four dimensions; (i)"fitness for use", (ii) natural scientific, (iii) economic and (iv) statistical, suggesting that studies of a high quality should have a sound natural scientific basis, that is also correct from an economic theory point of view and makes adequate uses of statistical theory. Söderqvist and Soutukorva (2009) identified a selection of factors relating to quality, firstly for valuation studies in general regardless of the valuation method used, and secondly for the application of particular valuation techniques. Each quality factor is subject to a short discussion and then further associated check questions, many of which require "yes", "no", "don't know" answers with "yes" being an indicator of good quality in most cases, although this is context-specific. The results of the application of this framework are then used in a qualitative evaluation of the overall quality of the study.

Söderqvist and Soutukorva (2009) suggest that the main difficulty in applying the QAI is in concluding and making a judgement as to the overall quality of the valuation study in question. Following their application of the framework to some 40 Swedish valuation studies during its development, three main categories of overall judgement emerged: 1) no serious shortcomings found, 2) more detailed quality assessment required before the study should be used in a policy context and 3) shortcomings in the study mean that it is unsuitable for use in a policy context. The authors suggest that while the QAI may not find a precise answer to a particular question, or produce a definite conclusion on overall quality, the QAI provides a framework for an evaluator to get an idea of the quality of a valuation study. Söderqvist and Soutukorva (2009) do not provide details of the time taken to evaluate a study, however the case studies provided in the article suggest that the quality factors develop into an extensive list of check questions, which may be very time consuming and therefore the practicality of applying the QAI is questionable. The authors also suggest that studies that were not "firmly rooted in welfare economics" or were "extremely site specific" were likely to require further quality assessment and therefore the framework is not necessarily applicable to all valuation studies.

Chapter 4 : Capacity in NRES Valuation

This chapter reviews the existing state of NRES valuation research, the type of work being carried out and the organisations and individuals involved. It draws on reviews of published work, as well as a review of ongoing projects that focus on NRES valuation or have this as a main component.

Key messages

A range of electronic databases are available, from which it is possible to search for published work on NRES valuation, such as EVRI, CAB abstracts, Web of Science and others. Searching can be problematic because of variation and inconsistency in classification of subject matter and use of key words.

The most frequently occurring keyword descriptors tend to be land-based., concerned with "land", "forests", "agriculture" and "landscapes". Many references also contain reference to "water" and "wetlands".

According to key word classification, the vast majority of valuation research is undertaken using economic, monetisation valuation methods, especially using contingent valuation. The most frequently used decision support method used in valuation research is Cost:Benefit Analysis.

NRES valuation research is dominated by the USA, but there has been a steady growth in capacity in the UK and Europe as a whole.

A focused selection of most cited abstracts confirmed a similar pattern, although more recently there have been developments in the use of deliberative methods.

The Environmental Valuation Reference Inventory (EVRI) provides a classified and information base that supports the transfer of primary benefit estimates to secondary applications.

A review of NRES-related projects showed that the main types and applications of valuation research are heavily focussed around the concept of ecosystem services, integrated biophysical modelling, interdisciplinary approaches, high levels of stakeholder engagement and providing decision support especially for policy choice.

In conclusion, there is a growing international capacity in NRES valuation that contributes to the design, appraisal, implementation and evaluation of policy interventions.

4.1 Review of CAB abstracts

A list of papers, book chapters, theses, conference papers and occasional papers was downloaded from the CAB abstracts. In order to capture references on both economic and non-economic valuation of NRES, papers dealing with the topics of "valuation", "contingent valuation", "non-market benefits", "willingness to pay" were searched for. Each record in the CAB Abstracts is reviewed by experts and assigned keywords which can be searched and it was assumed that a search using the subject heading would be most likely to provide a focussed selection of references dealing with valuation.

An "exploded" search using the "valuation" keyword (3,200 records) showed that it was linked to "non-market benefits" (1138), "contingent valuation" (885 records) and "willingness to pay" (1339 records). Other potential keywords such as "evaluation", or key words associated with social preferencing methods such as "participatory", "deliberative", "citizen's jury" could not be adequately searched in the CAB Abstract subject headings. However, the "valuation" and "non-market benefits" keywords search included some of the participatory and deliberative methods used in valuation research.

On reflection, it appears that while the classification of papers using economic approaches in valuation appears to be rigorous, finding valuation references using participatory and deliberative approaches is more difficult. This raises concern about the use of key words to classify research on NRES valuation and the need for a consistent nomenclature that includes economic as well as social and "environmental" approaches to valuation research.

Over 5,000 references were downloaded and sorted into a relational database format. Duplicates were discarded. However, a quick review of these papers showed that many of the references did not involve NRES valuation, but for example, involved the valuation of new scientific measurement protocols or rather than undertaking valuation themselves, were making the point that valuation was needed to account for the non-market of particular resources.

In order to focus the inventory more, a set of spreadsheet functions was used to search for specific keywords in the references abstract and subject heading. These included keywords associated with specific ecological goods and services as well as valuation methods and decision support systems. Some of these keywords and their frequency of occurrence are shown in Figure 4.1 (A full list is given in the Appendix C in Table C3, Table C4, and Table C5). In order to discard peripheral references in the inventory, only those including at least one keyword associated with a specific NRES characteristic or a valuation method were selected. This reduced the Inventory to approximately 3,200 references.

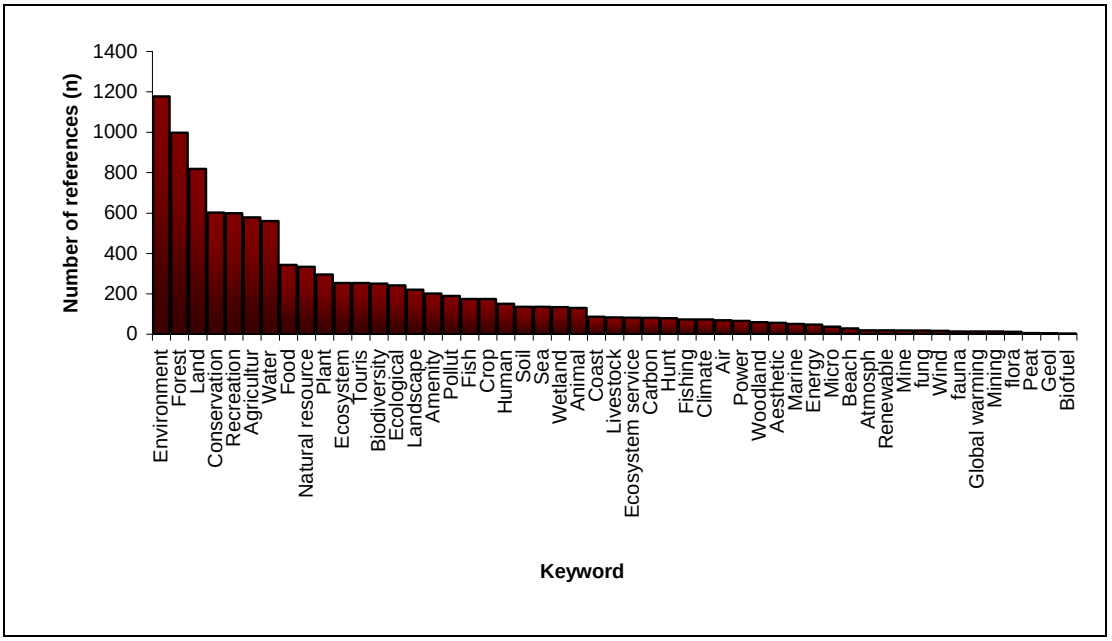


Figure 4.1. The number of times that keywords were found within the inventory of references drawn from CAB abstracts

While this collection of references provides an excellent starting point for an Inventory, it is recognised that a greater reduction of the database could be achieved by a more thorough review of these papers to find and discard those that are still peripheral to the topic. However, the Inventory still provides a quick and easy way of browsing a sizeable portion of valuation literature, much of which is relevant and useful. For example, it can quickly be seen that a

total of 135 references mention "soil", that 36 of these also include the words "contingent valuation", and that 5 contain the word "hedonic".

An analysis of the Inventory suggests that the vast majority of valuation research identified was undertaken in the USA (Table 4.1). Indeed many of the Federal States in the USA are associated with more valuation research than many nations. The UK is associated with a sizeable portion of the valuation research literature and ranks second. Other countries associated with significant valuation research include European countries such as Germany, Spain, Italy, Sweden, France, Finland and Norway and countries such India, China, Japan, South Africa and Brazil. The vast majority of this valuation research has been published in English. A smaller but significant amount has also been published in German, Spanish, "Chinese", and Italian. The pattern of research over time shows just a handful of publications appearing through the 1970s and 1980s and then expanding rapidly in the 1990s to current levels of approximately 300 valuation outputs per year. The vast majority of this research is in the form of journal articles, although book chapters and books and conference papers are relatively numerous (For more detail, see Appendix C, Table C1 and Table C2).

Table 4.1. Summary of the number of times that references in the CAB based inventory were identified in relation to a particular: a. Geographical location, b. Language, c. Year of publication and d. Type of reference.

a. Geographical location			**b. Language of reference**			**c. Year of publication**			**d. Type of reference**	
Location	***No.***		***Language***	***No.***		***Year***	***No.***		***Type of reference***	***No.***
USA	713		English.	2783		2008	223		Journal article	2541
UK	204		German.	131		2005	279		Book chapter	268
Germany	118		Spanish.	82		2000	149		Miscellaneous.	146
Spain	102		Chinese.	74		1995	126		Conf. paper	123
India	101		Italian.	57		1990	22		Bulletin.	149
Canada	88		French.	44		1985	18		Book.	92
Australia	87		Japanese.	43		1980	2		Journal issue.	31
Italy	85		Russian.	36		1975	2		Conf. proceed.	17
China	83		Polish.	28		1973	3			
Sweden	75		Portuguese.	17						
Japan	69		Czech.	13						
Europe	54		Hungarian.	12						
France	51		Slovakian.	9						

Table 4.2. Research organisations with 20 or more valuation outputs identified in the Inventory

Research organisation	*No of references*
Colorado State University	54
Swedish University of Agricultural Sciences	40
USDA Forest Service	36
University of California	32
University of East Anglia	31
Newcastle upon Tyne	31
University of Newcastle	30
University of Georgia	25
Iowa State University	24
University of Alberta	23
University of Wales	21
Michigan State University	21
University College London	20
Ohio State University	20
USDA Forest Service	20

The most frequently occurring keyword descriptors tended to be land-based. For example, many references contain “land”, “forests”, “agriculture” and “landscapes”. Many references also mentioned “water” and “wetlands”. Those explicitly dealing with NERC SUNR issues such as mineral extraction activities, energy and renewables, and soils are relatively few (See Appendix G). These individual keywords were classified as “land”, “water”, “air”, “energy” and “living organisms” and the resulting associated with valuation methods and decision support systems quantified (Table 4.3 to Table 4.6). It should be noted that classification is approximate and based on our judgement, and because of the quantity of papers found, it was not possible to review them individually. Difficulty was also encountered in classifying certain keywords to these broad NRES categories since, for example, forests could be classified with “land” to denote a particular use, or with “living organisms” to denote the object of valuation.

A feature of the keywords is that they are not mutually exclusive suggesting that valuation research must often consider linked resources and services rather than individual components (Table 4.3) (For more details, see Appendix C, Tables C3, C4, and C5). For example, the value of land is determined by its effect on other natural resources and ecosystem services. It is important in water quality (through filtration and purification), water regulation (through infiltration and storage), and plays a role in climate regulation through carbon sequestration. It is also important in production, in terms of soil fertility, and in the provision of habitat and biodiversity, which in turn may link to cultural benefits such as amenity, recreation and spiritual pleasure. We consider such linkages in the case of soils (see Appendix G).

Table 4.3. The frequency of keywords associated with air, land, water, living organisms and energy

	Total	Air related keywords	Land related keywords	Water related keywords	Living systems keywords	Energy keywords
Total		226	2007	717	836	112
Air related keywords	226	226	169	89	97	17
Land related keywords	2007		2007	378	561	74
Water related keywords	717			717	221	27
Living systems keywords	836				836	28
Energy keywords	112					112

The broad classification was cross-referenced to economic or social valuation methods and to decision support approaches (Table 4.4, Table 4.5 and Table 4.6) (For more details, see Appendix C, Table C6, Table C7, and Table C8). The keyword count of the Inventory references suggests that the vast majority of valuation research was undertaken using economic, that is monetisation valuation methods, especially contingent valuation (Table 4.4). However, other methods such as hedonic pricing, travel cost, benefit transfer, but to a lesser degree then contingent valuation.

Table 4.4. Economic valuation keyword search within references

	Total	Contingent valuation	Choice model	Market price	Production function	Random utility	hedonic	travel cost	benefit* transfer	production function	market price
Total		1220	61	98	46	36	151	205	83	46	98
Air related keywords	226	89	5	6	2	3	11	12	12	2	6
Land related keywords	2007	701	31	68	41	16	100	104	49	41	68
Water related keywords	717	316	13	24	9	12	35	55	34	9	24
Living systems keywords	836	304	16	23	10	10	28	45	17	10	23
Energy keywords	112	26		4	3		2	4	2	3	4

Keywords associated with social valuation, that is non-monetary methods (Table 4.5), are much less frequent then those associated with economic approaches. The words “deliberative”, “participatory”, “expert panel”, “focus group” and “citizen’s juries” are relatively infrequent and the search for “Q methodology” did not produce any hits. Although it is likely that valuation research using social methods is relatively restricted in comparison with economic valuation methods, it is likely that the search through the CAB Abstracts subject heading with the chosen keywords (“valuation”, “contingent valuation”, “non-market benefits” and “willingness to pay”) may not be suitable for finding valuation research which uses social methods. Indeed, it is possible that a range of stakeholder methodologies might be used in valuation research, which through lack of time, has not been picked up in this search. Once again, there is an issue here with respect to the consistent use of nomenclature and key words to classify NRES research outputs.

Table 4.5. Social valuation keyword search within references

	Total	participatory	deliberative	Discourse	questionnaire	focus group	citizen* juries	Health	DALY	QALY	Q methodology	expert panel	Delph	Systematic review
Total		45	7	5	206	32		216	2			2	6	
Air related keywords	226	1	1	1	8			25					2	
Land related keywords	2007	29	2	1	108	23	1	87	1			1	3	
Water related keywords	717	14	1		43	5	2	58	2			1	1	
Living systems keywords	836	21	3	1	50	9		59	1				2	
Energy keywords	112	3			3	1		8						

Keywords associated with decision-support methods suggest that the most frequently used decision-support method used in valuation research is cost-benefit analysis (Table 4.6). Other decision-support methods such as cost-effectiveness analysis or multi-criteria analysis are less frequently mentioned.

Table 4.6. Environmental and social valuation keyword search within references

	Total	cost*benefit analysis	value*benefit analysis	cost*effectiveness analysis	multi*criteria analysis	life*cycle analysis
Total		240	47	5	11	2
Air related keywords	226	27	6	1	1	
Land related keywords	2007	153	32	3	7	
Water related keywords	717	69	14	1	2	1
Living systems keywords	836	72	13	4	2	2
Energy keywords	112	10	2			1

4.2 Focused Reviews of Selected Abstracts

The following is a summary of a selection of publications taken from Web of Science that have been highly cited since their publication and thus may represent 'exemplar' studies in the field of natural resource valuation. Web of Science was searched according to broad natural resources plus valuation, e.g. "water AND valuation", "air AND valuation". The list is therefore not exhaustive and it should be noted that results are not necessarily the very first search results displayed, as these were not always relevant for this study. Furthermore publications were also selected to give an overview of authors, methods and state of science and therefore some more recent studies, with slightly fewer citations, have been reviewed to give a more current overview.

From the search terms used, the valuation of 'water' and 'biodiversity' areas appear to have been more widely studied than 'air' and 'energy'. However, the interaction of natural resources as ecosystem services and functions means that several of these publications appeared in more than one search and conversely others may have been overlooked owing to the specific keywords assigned to it. For example, more exemplar research relating to the valuation of renewable energy options may have required more specific search terms such as 'renewable', 'alternative', 'wind', 'tidal' etc. However, a more extensive keyword search of Web of Science was beyond the scope of this study. A more detailed review of these papers and a list of references can be found in Appendix H :

During the review of 'exemplar' publications taken from Web of Science, several common underlying themes emerged. The publications appeared to be highly cited for several reasons; often because they were the first apply a particular valuation technique in a certain context or scale, or the first to compare particular methods. Several also provided extensive reviews of techniques and studies or incorporated a large number of sources to produce a new valuation.

Many of the studies provided critiques and alternatives to the contingent valuation method, suggesting that respondents are unable to properly express their views, particularly those that characterise environmental concern and may also lead respondents to agree with the interviewer and/or overstate their willingness to pay Hein *et al*. (2006), Blamey *et al*. (1999), Aldred and Jacobs (2001).

Several publications, Hein *et al*. (2006), Turner *et al*. (2003), Ready *et al* (2004) etc., highlight the importance of the consideration of spatial and temporal scales, suggesting that both affect the values attached by different stakeholders. Furthermore, Hein *et al*. (2006) conclude that inclusion of spatial scales is crucial in the development of ecosystem management plans. Various authors also suggest that there may be many difficulties and inconsistencies in valuation studies on a global scale.

The importance of greater integration and understanding between social and ecological sciences is also a key theme (e.g. Pretty *et al*. (2003), Turner *et al*. (2000)), suggesting that lack of knowledge of ecosystem services can lead to under-valuation and lack of priority in decision making and therefore potential loss, destruction or substantial modification.

Finally, it also appears to be recognised that natural resource valuation is a very useful tool in environmental decision making, but that there are limits to its use.

4.3 The Environmental Valuation Reference Inventory

The Environmental Valuation Reference Inventory (EVRI) (http://www.evri.ca/) is a benefits transfer database. It is an international collaboration between Defra (UK), the Environment Protect Agency (USA), Environment Canada (Canada), the Department of Environment and Climate Change (NSW), Land Information (New Zealand) and the Ministère de l'Écologie, de l'Énergie, du Développement durable et de l'Aménagement du territoire (France). Its primary purpose is to serve as repository of information on monetary valuation for policy and research. Since the database is intended for benefits transfer use, it does not contain deliberative or participatory research.

The information and data are presented in six categories with sub-fields of data including the: i) "Study Reference" which contains the basic bibliographic information, ii) the "Abstract",

iii) the "Study Area and Population Characteristics", iv) the "Environmental Focus of the Study", which "describe the environmental asset being valued, the stressors on the environment, and the specific purpose of the study", v) the "Study Methods", which contain technical information on the study and a classification of the specific techniques that were used in the study, and vi) the "Estimated Values" or monetary output values that from the study and their units of measurement.

EVRI can be searched using five broad categories, the "Similarity of Environmental Issues", "Geographic Characteristics", "Specific Environmental Assets or Goods and Services", "Specific Geographic Characteristics" and "Economic Measure and Market Characteristics". Each of these contains sub-fields, some of which are described in Table 4.7.

Table 4.7. Selected field descriptors in the Environmental Valuation Reference Inventory

General Type of Environmental Goods and Services Valued
Extractive Uses, Non-Extractive Uses, Ecological Functions, Passive Uses, Human Health, Built Environment
Environmental Stressor
Bio-accumulative Substance, Biotechnology Organisms, Congestion/Crowding, Infrastructure Development/Habitat Conversion, Non-toxic Substance, Predominantly Anthropogenic Substance, Persistent Substance, Resource Extraction, Solid Waste, Toxic Substance,
General Environmental Asset
Air-General (local; regional; global), Land (wetlands/constructed wetlands; soil; preservation of agricultural land; surface mining reclamation; open spaces), Water (fresh water; salt water; estuaries; ground water; drinking water) Infrastructure/Manmade Environment (cultural monuments; buildings; flood control/dams; other assets), Animals/Plants/Etc. (endangered species; mammals; birds; fish; invertebrates; plants; trees; crops; microorganisms; fungi; bacteria; viruses), Human Capital (human health)
Economic Measure
Compensating Surplus, Compensating Variation, Consumers Surplus, Cost of Injury/Replacement, Equivalent Surplus, Equivalent Variation, Willingness to Accept, Willingness to Pay, Other
Valuation Technique
Actual Market Pricing Methods (actual expenditure/market price of output; change in behaviour [preventing, defensive]; experimental cash market value; prices), Revealed Preference (hedonic property; hedonic wage; travel cost method-single site; travel cost method-multi-site-regional / hedonic; travel cost method-RUM; replacement costs), Stated Preference or Simulated Market Pricing (contingent valuation -open ended; contingent valuation-payment card; contingent valuation-iterative bidding; contingent valuation-dichotomous choice; conjoint analysis; contingent ranking; combined revealed and stated preference),

Currently, 2,092 studies are described in the database, the majority of which are values derived for North America and Europe (Figure 4.2), supporting our findings from the search of CAB Abstracts. Most of this is associated with "Land", and land-related issues such as the man-made environment, "Water", and "Living Systems" (Plants and Animals) (Figure 4.3), again, supporting our finding from the review of CAB Abstracts. The vast majority of this valuation research has been undertaken using stated preference (1546), revealed preference (623) and actual expenditure (329) techniques. It is worth bearing in mind that EVRI can be searched at a much more detailed level and that research can also be cross-referenced. For example, a breakdown of the valuation techniques used shows that contingent valuation was by far the most frequently used approach to the valuation research documented by EVRI (Table 4.8).

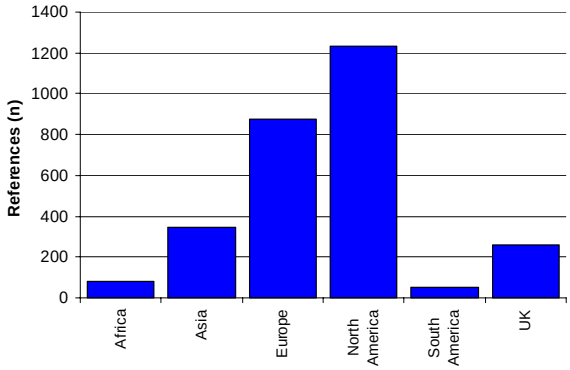


Figure 4.2. Summary of the number of references associated with different Geographical locations in EVRI

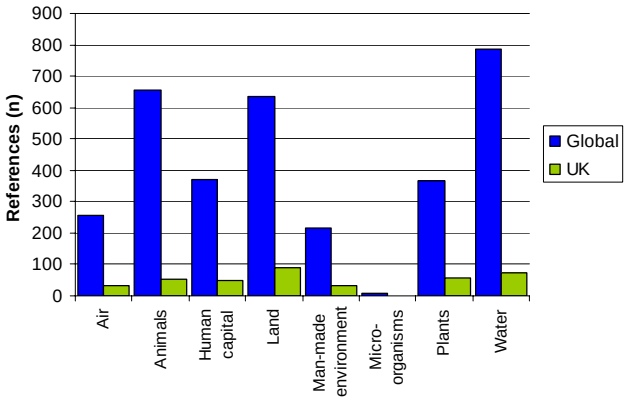


Figure 4.3. Summary of the number of references associated with different Environmental assets in EVRI

Table 4.8. Summary of the number of references associated with different valuation techniques in EVRI

Valuation technique	Reference (n)
Data models	23
Choice experiments	44
Actual expenditure/market price of output	269
Averting behaviour	49
Change in productivity	45
Conjoint analysis	106
Contingent ranking	45
Contingent valuation - dichotomous choice	525
Contingent valuation - iterative bidding	150
Contingent valuation - open ended	442
Contingent valuation - payment card	235
Experimental cash market	13
Hedonic - property	175
Hedonic - wage	19
Travel cost method – multi-site – regional/hedonic	138
Travel cost method – Random Utility Model	77
Travel cost method – single site	184

4.4 Project Profiles

A review of recently completed or on-going projects was undertaken using material from published and internet sources in order to extend consideration of current approaches to valuation of NRES. Since a very large range of international projects were identified, with sponsorship ranging from Research Councils through to Government Agencies, Charities and Private Organisations, the review was necessarily selective. Seven studies that illustrate current research directions are reported here, namely:

- Valuing the Arc (http://valuingthearc.org/)
- The Natural Capital Project (www.naturalcapitalproject.org/about.html)
- The Nature Valuation and Financing Network (http://topshare.wur.nl/naturevaluation)
- MIMES (http://www.uvm.edu/giee/mimes)
- Rubicode (www.rubicode.net/rubicode/index.html)
- The EcoValue Project (http://ecovalue.uvm.edu/evp/doc_research_team.asp) and
- TEEB(http://ec.europa.eu/environment/nature/biodiversity/economics/index_en.htm)
- Rural Economy and Land Use (RELU) Programme (http://www.relu.ac.uk/)

These and other ongoing projects serve to significantly strengthen the capacity for valuation of NRES. These are briefly reviewed in turn.

4.4.1 Valuing the Arc

This is a large on-going international project that is examining ecosystem services provided by the Eastern Arc Mountains of Tanzania, funded by the Leverhulme Trust. It is seeking to understand the contribution they make to human welfare, and in particular to identify ways in which these resources can be managed sustainably. In doing so, this research aims to provide critical information to policy-makers in Tanzania and contribute to the wider field of ecosystem services research. A distinctive feature of the project is its interdisciplinary nature, combining understandings of natural resource systems and wider societal and institutional contexts. The aim of the programme is to develop a general procedure for analysing and synthesizing information on ecosystem services, and for identifying institutions capable of capturing ecosystem values in decision-making. The themes considered in the project include: hydrological services; carbon-related services; timber services; non-timber forest products; ecotourism services; pollination services; governance and natural resources; and, priorities for biodiversity and associated existence values.

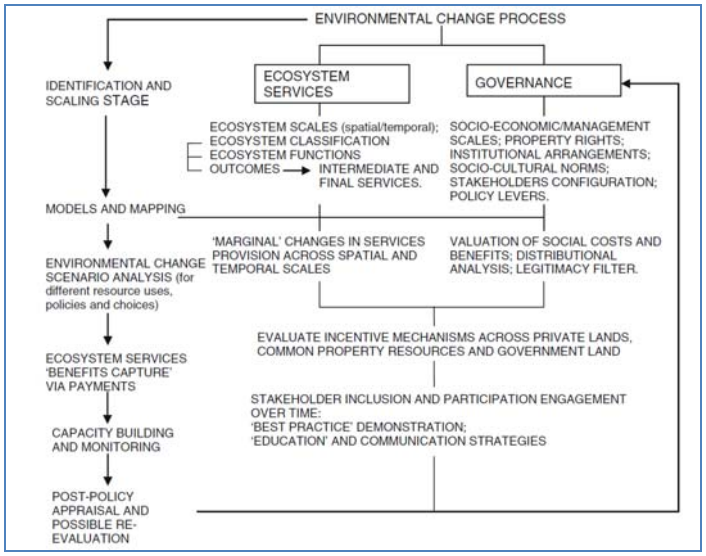


Figure 4.4. The ecosystem service framework (after Turner and Daily, 2008)

The project will run for five years; and is still in its early stages so results are presently limited. However, some of the underpinning review work has been completed. The 2008 Annual report highlights some key conclusion from this initial work. It was found from a review of theoretical work[5] that the literature is deficient in that there appears to be 'no systematic approach to ecosystem service research that incorporates current economic valuation approaches'. It is argued that the valuing the Arc Project will attempt to fill this gap.

Reflecting on some of the more general issues related to taking the so-called 'Ecosystem Service Framework' (ESF) (Figure 4.4) forward, Turner and Daily (2008) suggest that information at scales useful for decision makers on how people benefit from specific services is lacking, and that better integrated approaches are required for modelling, mapping and valuing ecosystem services. They argue for tighter classifications of ecosystem services and a careful the distinction between intermediate and final products as a preliminary step to the achieving a sound valuation of ecosystem services.

Valuing the Arc illustrates the new, interdisciplinary perspectives that the Ecosystem Service Framework brings to the study of natural resources, and it is increasingly likely that we will see the issues that surround them being framed around the notion of the goods and services that 'natural capital' can provide. The work also demonstrates the importance of underpinning the valuation studies with robust process-based biophysical models and the key role that mapping plays in the development of policy and management responses. Both areas are important focal points for NERC-related science.

4.4.2 Natural Capital Project

Our review confirms that there is increasing interest in the development of spatially explicit modelling frameworks for ecosystem services and that these are providing an important arena for a range of interdisciplinary work. Some of the most advanced modelling approaches are

[5] http://valuingthearc.org/reports_publications/Valuing%20the%20Arc_Annual%20Progress%20Report_2008.pdf

those associated with the Natural Capital Project[6]. This initiative is being led by the Woods Institute for the Environment at Stanford University, and is sponsored by the US Nature Conservancy and WWF. The project aims to "provide maps of nature's services, assess their values in economic and other terms, and ….incorporate those values into resource decisions".

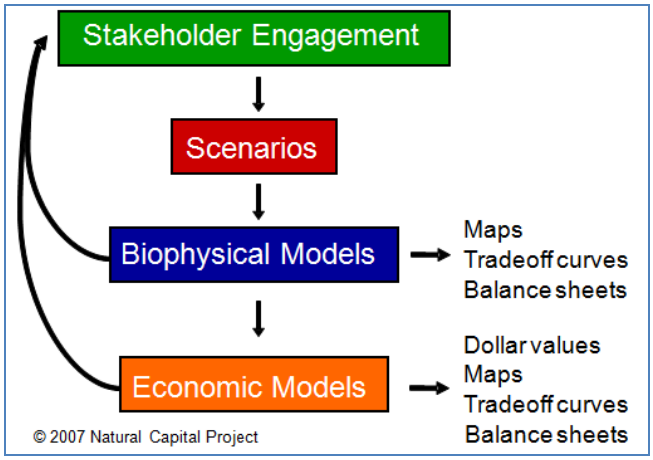


Figure 4.5. Structure of Natural Capital Initiative InVEST Toolbox

The Natural Capital Project team works in partnership with a number of other organisations, and in fact are collaborating in the *Valuing the Arc* study, supporting the latter's aim of developing GIS models for all the services associated with the Eastern Arc Mountains. A key analytical resource provided by the natural capital project is the InVEST toolbox (Figure 4.5). This has been designed to support stakeholder involvement in defining management or policy issues and the construction of change scenarios. A suite of biophysical modes are then used to explore the consequences of different options or choices. Outputs are generated in the form of maps, trade-off curves and 'balance sheets'.

The InVEST runs as a set of script tools in the ArcGIS ArcTool Box environment, and currently includes models for carbon sequestration, pollination of crops, managed timber production, water pollution regulation and sediment retention for reservoir maintenance. The modelling framework is customisable, and generally requires land cover information as a basic input to the analysis. In the tool box there is also a biodiversity model that permits the analysis of tradeoffs between biodiversity and ecosystem services. It is planned that the range of biophysical models offered will be extended to cover flood mitigation, agriculture production, irrigation, open-access harvest and hydropower production. The modelling tools currently only concern ecosystem services associated with the terrestrial and freshwater systems, but the model set may be extended to cover marine areas, especially reefs and other coastal systems.

As Naidoo *et al*. (2008) have argued, unless ecosystem services can be quantified and valued and their areas of production mapped, it will not be possible to identify and target regions in which conservation efforts might benefit both biodiversity and sustain the output of ecosystem services. From their analysis of service and conservation priorities at global scales, they suggest that there is little current evidence to suggest that areas of high biodiversity provide more services than regions chosen randomly. However, they also observe that their

[6] http://www.naturalcapitalproject.org/about.html

analysis is provisional, based on a set of "imperfect global proxies". Thus they conclude that "an ambitious interdisciplinary research effort is needed to move beyond these preliminary and illustrative analyses to fully assess synergies and trade-offs in conserving biodiversity and ecosystem services" (Naidoo *et al*. 2008. 9495). Analytical Platforms such as that being developed through the Natural Capital Imitative and studies such as *Valuing the Arc* therefore represent important elements of this new and evolving research agenda.

4.4.3 The Nature Valuation and Financing Network

The Nature Valuation & Financing Network (Figure 4.6) at Wageningen University has a number of objectives including the following:

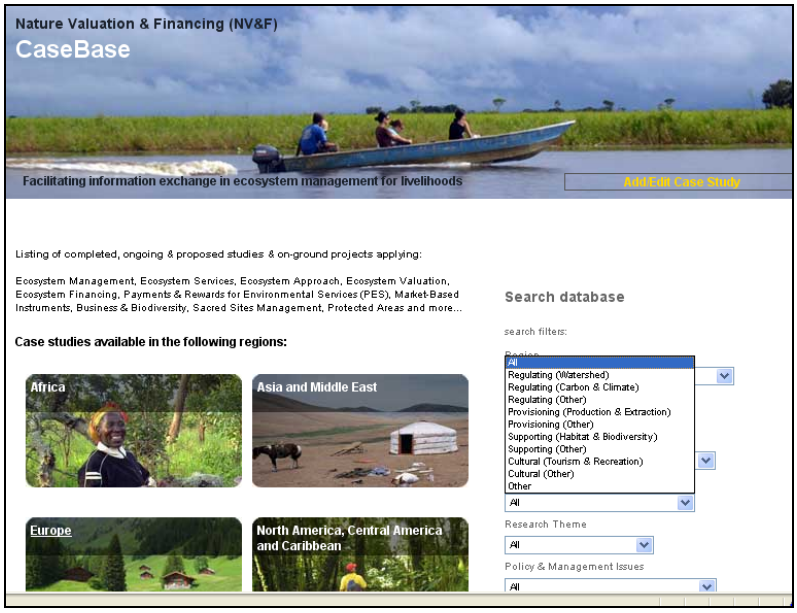


Figure 4.6. The Nature Valuation and Financing Network CaseBase page used for retrieving document case study valuation research

1. Develop guidelines and instruments for ecological, economic and socio-cultural valuation of goods and services, application of valuation and financing in decision-making instruments
2. Stimulation and collection of data on case studies in CASEBASE for the use of researchers and policy makers (Figure 4.6)
3. Provision of a platform for partnership development for collaboration and research, discussion groups and working groups
4. Support of development of National Platforms for Nature Valuation and Financing
5. Stakeholder engagement and facilitation of ecosystems knowledge

Projects held by the network include the:

- Ecosystem Services & Sustainable Management (IUCN CEM)
- Water & Nature Valuation (IUCN WANI)
- Task Force on Cultural and Spiritual Values of Protected Areas (IUCN WCPA)
- Payment for Ecosystem Services (Forest Trends)

4.4.4 MIMES: Multi-scale Integrated models of Ecosystem Services

The MIMES Initiative[7], led by the Gund Institute for Ecological Economics at the University of Vermont (very closely related to the EcoValue project – see further below), illustrates other types of collaborative modelling approach that are currently being explored in relation to NRES issues. The aim of this initiative is to develop a suite of dynamic ecological economic computer models that deal with integrating understandings of ecosystem functioning, ecosystem services, and human well-being at a range of spatial scales. The work is built around a set of interrelated sub-models that focus on atmosphere, lithosphere, hydrosphere, biosphere and anthroposphere, and uses input data to explore the relationships between and how development, management and land use decisions will affect natural, human and built capital.

MIMES appears to be a more wide-ranging and more diverse suite of modelling tools than those available through the Natural Capital Project, and the focus of the work as much on building a community of users as on specific algorithms. It is also intended as an educational as well as an analytical facility.

4.4.5 The EcoValue project

A further example is the EcoValue project which "draws from recent developments in the economic valuation of ecosystem services, ecological-economic database design, WWW technology, and spatial analysis techniques to create a web-accessible, GIS decision support system for the valuation of nonmarket goods and services associated with distinct land cover types" (e.g. Figure 4.7). Using a set of decision rules for selecting empirical studies from published literature, the EcoValue team uses a benefit transfer approach to derive values for ecosystem goods and services for research, decision-making and planning. The EcoValue research team has developed a set of decision rules for selecting empirical studies from the published literature. The total value of ecosystem services is derived by careful matching of the spatial resolution and coverage of the original "study sites" with the characteristics of the "policy site".

[7] http://www.uvm.edu/giee/mimes

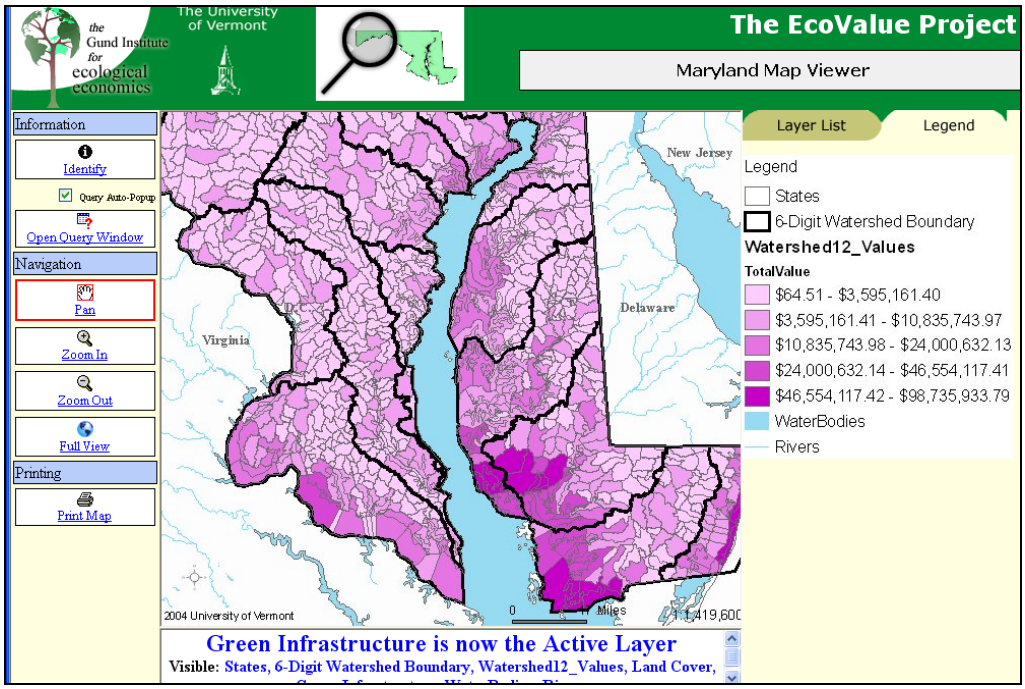


Figure 4.7. A web-based GIS analysis of ecosystem values developed by the EcoValue Project for Maryland, USA.

The values are converted to 2001 US$ equivalents and periodic review of the database and maps are given. This approach has provided "conservative" baseline economic values of the anthropocentric value of ecosystem goods and services. Where uncertainty is excessively high, or where no applicable peer-reviewed research exist, economic values are not estimated for those land cover types, even though it may be evident that they have high anthropocentric values.

4.4.6 Rubicode

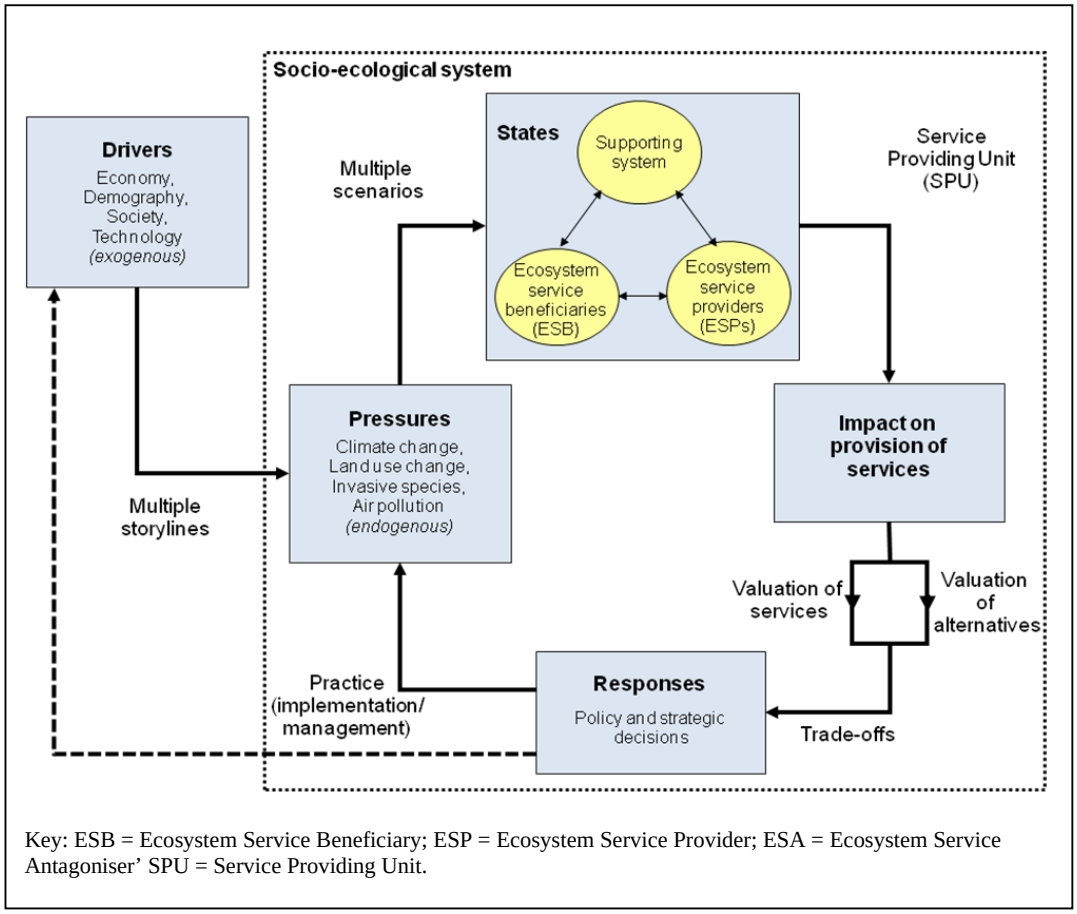
The recently completed Rubicode Coordiated Action[8] was funded under the EU 6th Framework Programme, and has involved 24 core partners and many other associated organisations from across Europe. It involved extensive networking activities, aimed at developing a conceptual framework for managing dynamic ecosystems. The aim was to better understand how, despite disturbance, ecosystems can retain their basic functioning, output of ecosystem services and resilience characteristics. The work has resulted in a series of workshops and review publications that have better articulated the idea of a 'Service Providing Unit' (SPU) initially proposed by Luck *et al.* (2003), who argued that instead of defining a population or organisms along geographic, demographic or genetic lines, it could also be specified in terms of the service or benefit it generates at a particular scale. For example, an SPU might comprise all those organisms contributing to the wildlife interest of a site or region, or all those organisms or habitats that have a role in water purification in a catchment.

The conceptual framework built around the SPU concept through the Rubicode Project is illustrated in Figure 4.8. (see Vandewalle *et al.*, 2008). Clearly it has a number of similarities to the ESF framework proposed by Turner and Daily (2008) (see Figure 4.4), in that it shows

[8] http://www.rubicode.net/rubicode/index.html

how valuation studies are embedded in the wider decision-making processes that surround the management of ecosystem services. An original feature however, is the explicit link it makes to the DPSIR indicator model. The latter has been widely used to characterise natural resource systems, and so the Rubicode model is useful in that it helps provide a more integrated perspective.

In the context of the present study, several of the outputs of the Rubicode Project are worth noting. First, the detailed examination made of the relationships between functional traits and ecosystem services. A functional trait is a feature of an organism which has demonstrable links to the organism's function or role, and its functioning or performance. These traits control the way in which an organism might influence the output of an ecosystem service (effects traits) or the way it might respond to pressures (response traits). The Rubicoide Project has both demonstrated how a traits-based approach to NRES can be developed and documented the evidence base supporting it (de Bello *et al*. 2008). As a result we are much better placed to understand the links between ecosystem services and biodiversity.



Key: ESB = Ecosystem Service Beneficiary; ESP = Ecosystem Service Provider; ESA = Ecosystem Service Antagoniser' SPU = Service Providing Unit.

Figure 4.8. A framework for linking direct and indirect drivers, pressures and responses as a coupled socio-ecological system for assessment of the effects of environmental change drivers on ecosystem services (after: Vandewalle *et al*., 2008).

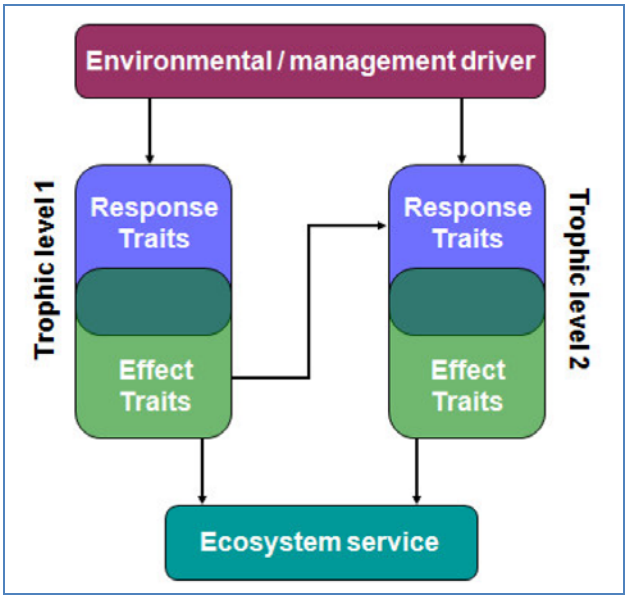


Figure 4.9. A traits-based analysis of ecosystem services

A second important output from the Rubicode Project is the review of dynamics of ecosystem values and preferences. As the basis of their work Kontogianni *et al*. (2008) asked "How do human preference and values for ecosystem services change through time?" and "Do we have the methods and data necessary to assess these changes accurately?". The conclusions they draw are probably relevant to the factors shaping valuation of natural resources in general. They found that it was difficult to be conclusive about WTP values being stable over short to medium time periods, and that they are highly likely to change in the longer term. This makes the task of modelling the dynamics of preferences very complex.

Their review of Kontogianni *et al*. (2008) considered both empirical evidence of both demand-driven and supply-driven changes in values, and a range of integrated ecology-economy models, and dynamic bio-economic models, as representative approaches to modelling supply-driven dynamics. They suggest that to take such work forward we probably need "the integration of insights, methods and data drawn from evolutionary and behavioural economics as well as from integrated ecology-economy models" if we are to understand the dynamics of ecosystem values.

4.4.7 TEEB: The Economics of Ecosystems and Biodiversity

The TEEB programme[9] was initiated by the meeting of environment ministers of the G8 countries and the five major newly industrialising countries in Potsdam in March 2007. The German Government put forward the idea of a study on 'The economic significance of the global loss of biological diversity', as part of the so-called 'Potsdam Initiative' for biodiversity. The resulting work has focussed on evaluating the costs of biodiversity loss and the associated decline in ecosystem services worldwide, and to compare them with the costs of effective conservation and sustainable use. Overall the aim is to increase awareness of the value of biodiversity and ecosystem services and stimulate development of cost-effective policy responses.

[9] http://ec.europa.eu/environment/nature/biodiversity/economics/index_en.htm

The work is being undertaken in two phases: the first, interim stage has now been completed, and has reported its initial findings to the COP9 meeting in 2008 (European Commission, 2008); the second more extensive element will extend though to 2010, with the final report being delivered to COP10. A number of components are planned for this final phase that include: an extensive meta-analysis of the state of knowledge of the relationship between biodiversity, ecosystems and ecosystem services, biodiversity in ecosystem resilience; thresholds in ecosystem functioning; the measurement of services and valuation methods; the ethics and discount rates; and, ultimately an assessment of the costs of the loss of biodiversity and ecosystem services. In addition to analysing the robustness of the underpinning science, however, the outputs will also be prepared to meet the needs of a range of end-users, including policy makers, administrators, business and industry and consumers and citizens. The outputs of the TEEB study will follow in the tradition of the Millennium Ecosystem Assessment (MA, 2005), and are likely to form a significant input into the planned follow-up activities[10].

4.4.8 The Rural Economy and Land Use Programme

The Rural Economy and Land Use Programme (RELU) is an integrated 6 year research programme, which consists of a series of projects. It was established primarily because of recognition of the difficult challenges faced by rural areas in terms of management of land. An important facet of RELU is its intention to foster interdisciplinary research, especially because it aims to bring about integrated solutions in rural areas and because of the increasing recognition of the multi-dimensional benefits of land, for example, in terms of flood defence, biodiversity provision, and amenity. RELU has been supported by a number of stakeholders, in particular, the Economic and Social Research Council (ESRC), the Biotechnology and Biological Sciences Research Council (BBSRC), Natural Environment Research Council (NERC), the Scottish Executive Environment and Rural Affairs Department (SEERAD) and the Department for Environment and Rural Affairs (Defra).

A review of some of the projects suggests that a variety of approaches to determining preferences are being used. Several projects such as the “Modelling the Impacts of the Water Framework Directive” the “Collaborative Deer Management” project and the “Implications of a Nutrition Driven Food Policy for the Countryside” project include monetary valuation components, for example, to determine the social benefit to society of the Water Framework Directive on health, amenity, and recreation, the economic costs and benefits associated with various deer management options and social wiliness to pay for safe food. Several projects on the other hand integrate deliberative and participatory preferences as part of their approach. The “Integrated Management of Floodplains” developed a narrative of different management options based on stakeholder and institutional analysis, field measurements and hydrological models, which were then used to determine the preferences of stakeholders. The “Management Options for Biodiverse Farming project” developed an integrated environmental, economic and social model by integrating a set of farmer-defined preferences for farm level economic and environmental benefits to determine the management responses of farmers, and hence the ecological consequences, of external stimuli and agricultural futures. The “Sustainable Uplands: Learning to Manage Future Changes” project used a process of stakeholder engagement, expert knowledge and modelling to iteratively arrive at preferred management options for upland areas.

[10] http://www.ciesin.columbia.edu/repository/entri/docs/cop/CBD_COP009_dec15.pdf

4.6 Conclusions

The projects reviewed here illustrate that the main types and applications of valuation research with respect to NRES are heavily focussed around the concept of ecosystem services rather than 'natural resources' per se, and as such the discussion of valuation methods and purposes is difficult to disentangle from that surrounding the economics of biodiversity change. There are of course many commonalities between the valuation approaches for biodiversity and natural resources more generally, and so the current attention on ecosystem services is clearly leading to a considerable strengthening of capacity in terms of valuation methodologies.

An emerging research focus is the integration of ecological and economic analyses and their use in making assessments, in marginal terms, of the changes in service output resulting from modifications or interventions to the underlying ecosystem. A focus on the implications of change in ecosystems rather than their total value of ecosystems implies that a good understanding of the sensitivity of service output to underlying biophysical processes is available. Such an understanding appears to be the key challenge for future scientific work. We need better biophysical models and a better understanding of how management interventions might impact upon service output; we also need to understand how both might be transformed in the context of indirect drivers of change, such as those related to climate. These models also need to be spatially explicit and be capable of integrating information across a number of discipline areas. Thus priorities for NERC regarding NRES valuation would seem to be in supporting the development of the integrated tool box concept: future research in these areas is inescapably inter-disciplinary.

It could also be argued that future research in the area of NRES valuation is inevitably trans-disciplinary. Even the small sample of projects described here demonstrates that these topics have considerable policy resonance. Initiatives such as the ones described here all focus on including stakeholders in shaping research agenda, and providing tools to stakeholders to support the decisions that then have to be made. Future research challenges therefore will need to involve both inter-and trans-disciplinary skill base.

Chapter 5 : Stakeholder Interest in NRES Valuation

This chapter reports on the assessment of stakeholder interests in, and influence over, NRES valuation. It draws on reviews of literature and the questionnaire survey of NRES researchers.

Key messages

- A wide range of stakeholders were found to have interest in and influence over valuation research, in particular because through national and international policy, there is increasingly a policy commitment to provision of non-market environmental services.
- Most research appears to be funded at a government level, although NGOs and to some extent industry bodies are also involved.
- As a major provider of environmental data and knowledge, the importance of NERCs role in valuation research is significant.
- The value of NERC's role in valuation could be greatly increased by forming strategic alliances and networking
- In order to achieve this, NERC could locate itself strategically with the identified "Key players" to engage in policy-oriented and sustained research.

5.1 Sponsors of NRES research

The questionnaire survey of NRES researchers showed that a wide range of stakeholders were sponsoring valuation research. The majority of funding appeared to be provided by National Government Agencies and statutory bodies (Table 5.1). Lesser mention was made of the non-governmental and charity sector (e.g. RSPB), and industry organisations such as the UK Milk Development Council, the Canadian Water Council. Reference was made to collaborative interdisciplinary programmes referred to earlier, including the RELU programme.

Table 5.1. Sponsors of NRES valuation research identified during researcher survey

Sponsors of NRES Valuation Research:

Eurocontrol, EPSRC, the National Science Foundation, the National Science Foundation, the Packard Foundation, the Winslow Foundation, the Initiative for Renewable Energy and the Environment, the Forestry Commission, the US Environmental Protection Agency, NOAA, the Peconic Estuary Program, Sea Grant, NSF, NERC, the Environment Agency, the European Union, the Association of Commonwealth Universities, Natural England, Royal Horticultural Society, National Trust, Department for Transport, ESRC, Forestry Commission Scotland, Dept Env & Transport & Regions, HeFCE (via dual funding), British Academy, Arts and Humanities Research Board, British Council, Scottish Office (SOAEFD), Irish Environmental Protection Agency, Scottish Government (RERAD), German Government (BMBF), RSPB, Defra, BBSRC, Malaysian Government, Scottish Government (RERAD), Canadian Water Network; Health Canada, Milk Development Council, RELU, US Government, World Bank, DEFRA, Australian Government, U.S. National Park Service.

5.2 Stakeholders in NRES research

As part of the questionnaire survey, NRES researchers were also asked to identify those they considered had an "interest in" and "influence over" valuation research. These were collected and the frequency of response tabulated (Appendix C, Table C9). The table was divided into "key players", "subject", "context setter" and "crowd" using a classification approach developed by Lindenberg and Crosby (1981) and later used by and Eden and Ackerman (1998) and Byson (2002) (Figure 5.1). The classification can be used to determine how stakeholders might be engaged and how future policies could be devised. Thus, whilst "key players" are important because they have high interest and influence over the phenomenon of investigation (in this case, NRES valuation research), "context setters" by contrast are important because although influential, they have little interest in the issue, and this may cause friction. "Subjects" on the other hand have high interest in the phenomenon, but little influence and therefore lack the capacity for impact, unless they form alliances with like-minded stakeholders. The "Crowd" have little interest or influence in the phenomenon of investigation and are therefore generally not engaged.

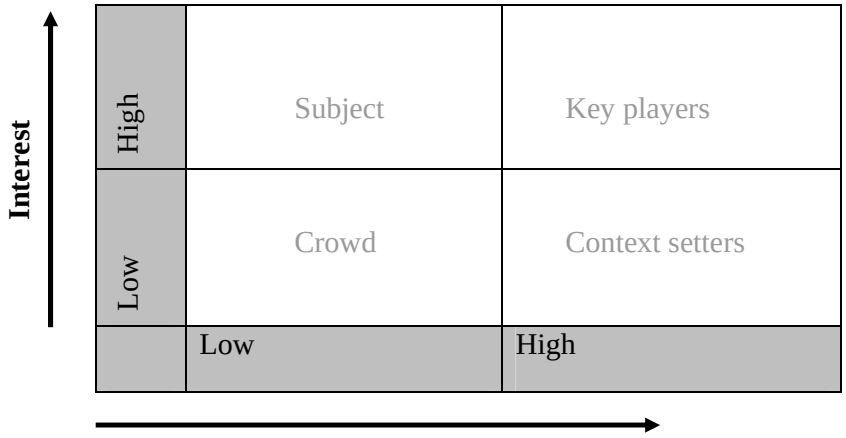


Figure 5.1. An analytical categorisation of Interest and Influence matrix which can be visually used to classify stakeholders into groups

The feedback from the detailed questionnaire showed that most of the stakeholders identified by the respondents were considered to be "Key players" and "Subjects". This feedback along with the review of the Inventory, also informed the more detailed mapping process that is shown in the Appendix I. NERC was mentioned as a provider of funding for valuation research (Table 5.2), but was not listed as a stakeholder with interest in or influence over valuation research.

In our stakeholder evaluation (contained in Appendix I), we suggest that NERC is a "Context setter", since its current primary objective is to provide baseline physical data. It is worth noting that stakeholder interest and influence can change over time. For example, some stakeholders may form alliances to increase their influence, and stakeholder analysis is typically used to identify how such alliances might form or be encourage and which

stakeholders might be involved. Context setters can also become Key players, if interest in the key phenomenon of investigation increases.

One recommendation is that NERC could try to locate itself within the network of stakeholders with an interest in valuation research, for example, by interacting with the key players. These stakeholders might for example, be invited to join a panel or programme that could help to elucidate how NERC's role in valuation could become more prominent and how NERC data could be made more accessible and suitable in valuation research. Strategic alliances for example with other Research Councils could move NERC into the Context Setter role for NRES valuation research. Increased funding of NRES valuation research by NERC itself would move it into the "Key Player" category.

Table 5.2. Classification of stakeholder interest and influence in valuation as specified by Questionnaire respondents

Subject	Key players
Association of Gardens Trusts; CPRE; Defra; Garden History Society; General Public; LBAP; Natural England; Non-profit Land Trusts; scientists; Scottish Natural Heritage; SEPA	Academics; AHRC/EPSRC Science and Heritage Research Programme; AONB offices; CABE; CLG; Defra; Direct resource users; English Heritage; Environment Agency; European Union; farmers; Fishing companies; Forestry Commission; Government bodies dealing with natural resource issues; Historic House Association; JNCC; Local authorities; Milk Development Council; Ministry of Fisheries and Marine Resources; National Trust; Natural England; Professional institutes; Property owners organisations; Royal Horticultural Society; The Nature Conservancy; United States Department of Agriculture; United States Fish and Wildlife Service; Water companies; Welsh Assembly Government; WWF
Crowd	**Context setter**
Cairngorms National Park Authority ; CLA; Defra; Department of Agriculture; EU land use and habitats policy departments; farmers; NFU; RSPB; World Wildlife Fund; Environmental Protection Agency, NERC	FAO; Defra; Government departments; World Bank

5.3 Use of NRES valuation data by the legal system

Although a large number of stakeholders have an interest in valuation research and it is quite frequently undertaken for project appraisal, the use of valuation in legal cases appears to be relatively scarce, particularly for non-use values. A discussion of this is presented in Appendix G.

Chapter 6 : Perceptions of Valuation: Results of a Survey of Researchers

This chapter reports the findings of surveys of respondents from the research community to elicit views on the current state of valuation science and priorities for the future. The reporting below takes the perspective of the respondents throughout, unless otherwise stated (For full details of responses, see Appendix A).

Key messages

- There are different types of users and providers of valuation research, ranging from consultants deriving NRES values for projects impact assessment, through to academics concerned more with research methods.
- Although most surveyed respondents noted that the integration of the underlying science presented some problems, half of these thought that these could be overcome relatively easily.
- Much progress had been made in recent years in interdisciplinary working necessary to support NRES valuation.
- The concept of ecosystems services provides a valid framework for constructing the value of natural resources.
- The majority of respondents thought that existing data and methods were broadly fit for purpose, but there was scope for improving coverage and quality to provide more complete and robust estimates of value.
- Identified priorities for future development of capacity in NRES valuation include:
    - improved integration of existing data sets and of quantitative and qualitative valuation methods,
    - improved quality control in the use of valuation methods, especially stated preference techniques,
    - continued development of integrated biophysical and socio-economic modelling of NRES at relevant spatial and temporal scales, addressing key areas of risk and uncertainty
    - methods and benefit transfer,
    - improved understanding of values through the use of deliberative participatory methods,
    - more use of direct observations of actual behaviour, and
    - improved understanding of the role of property rights and entitlements.
- There is a critical need for best practice guidance on the use and evaluation of valuation methods for project and policy appraisal.
- Valuation is perceived to be an essential component of a research strategy for the sustainable use of natural resources, and essential component of policy relevant research.
- Researchers considered that sponsorship of long-term integrated research projects was needed to enhance NRES research capability and contribution.

6.1 Perceptions of Suitability of Valuation data and Methods

Figure 6.1 shows responses to questions by those engaged in Natural Resources and related Ecosystem Services (NRES) research about the suitability of data, methods and procedures for NRES valuation studies. Most respondents thought that data sources and scientific

understandings were suitable for the purposes of valuation research, although increased scientific knowledge tended to create further "known unknowns". The great majority, perhaps not surprisingly thought their valuation research was suitable for decision support. Although 90% of respondents identified some problems and challenges with the integration of the sciences required for valuation, half of these thought the problems could be easily overcome. The reasons for their assessments are discussed below.

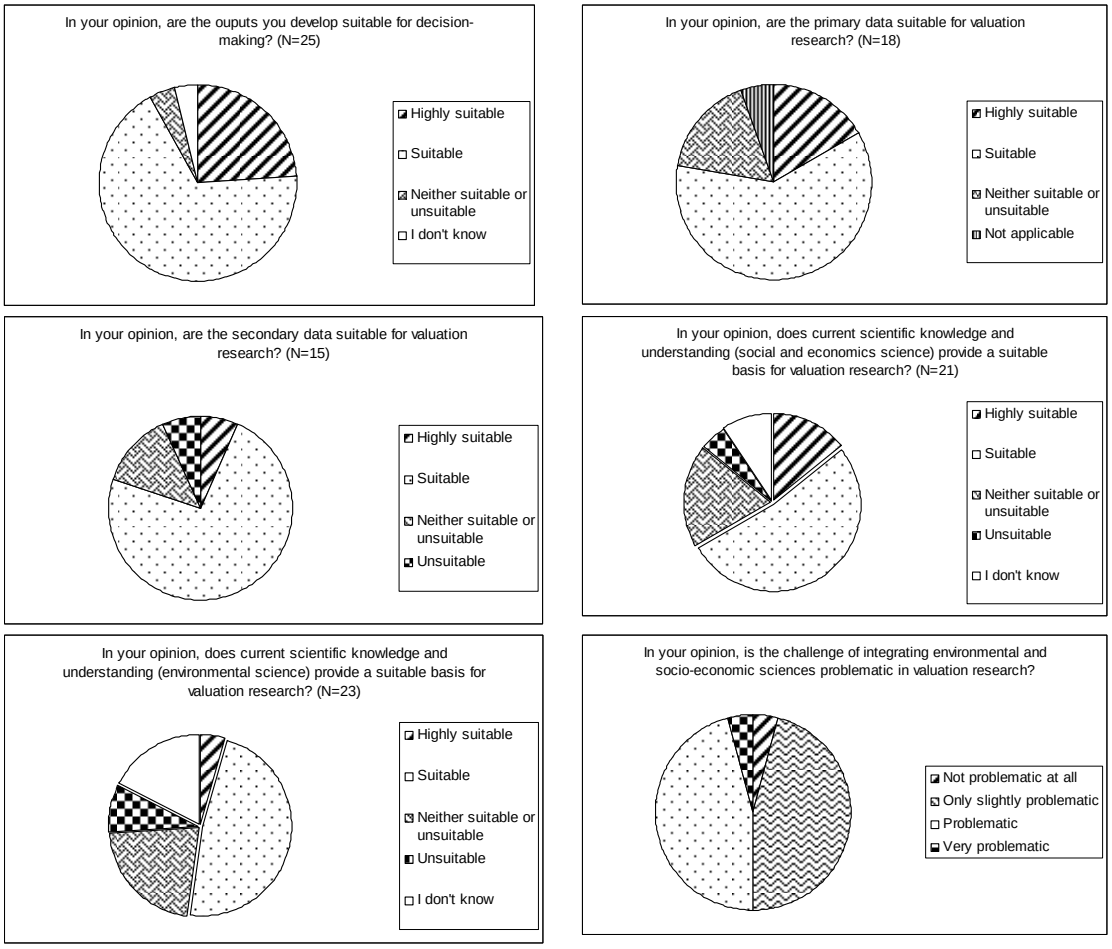


Figure 6.1. Respondent Views on the Suitability of Valuation Data and Processes

6.2 Ecosystem services valued, and drivers of environmental concern

The majority of respondents were involved in research on the NRES topics of "land", "water" and "living systems", covering a range of ecosystem functions and services (see Chapter 3), some specialising in transport, energy or agriculture. Much of their valuation work was associated with proposed project development or policy appraisal.

There were four main grouping of users and providers, reflecting a continuum from practitioner to (pure) research applications:

- first, the use of valuation to support major investment decisions, mainly the preserve of consultants;

- second, the use of valuation for policy design and choice (that is policy driven), mainly involving consultants and research contractors;
- third, valuation as part of longer term strategic reviews (policy relevant), mainly involving research institutes and university departments; and
- fourth, new developments in valuation methods (usually applied to policy relevant issues) usually undertaken by university academics. This continuum is also reflected in differences in audiences, techniques used and the means of communicating outputs.

It was obvious that respondents clearly saw that valuation studies made the link between environmental and ecological health and social welfare. The wish to explore and communicate this relationship seemed to distinguish those natural scientists that engaged in the valuation process from those that did not. A number of respondents considered that most natural scientists are motivated to research fundamental relationships, leaving it to others to interpret research findings for different purposes.

6.3 Valuation methods

Without exception, respondents found it easy to draw distinction between **evaluation** used to identify and quantify emissions and impacts in the context of Environmental Impact Assessment, and **valuation** associated with putting monetary values and relative social preferences on impacts associated with environmental change. It is the latter that is of concern here. Most natural scientists were historically familiar with evaluation but reported that their engagement with valuation had increased, typically over the last five years or so.

It was almost universally felt that the concept of ecosystems services provided a useful framework for the identification and valuation of Natural Resources. It had, however, in the view of some respondents, raised unrealistic expectations that all ecosystem services could be reliably valued in monetary terms. A number of respondents alluded to the dangers of forcing monetary values where none reliably existed: as one reported, “any impacts that cannot be monetised should be highlighted”. Furthermore, there was concern that monetisation could lead to false assumptions of perfect substitutability.

Respondents reported that they had, between them, used a variety of methods, including cost and income based methods, stated preference, revealed preference, and a range of participatory methods. The majority of respondents suggested that the methods used were at least “suitable” for the purpose of valuation.

Academics considered that much could be done to improve the reliability of stated preference methods. There is concern that responses can be manipulated by the framing and context of the valuation choices, and much more needs to be done to facilitate consistency in questions, answers and analytical methods. These techniques become unreliable when people are asked questions that go beyond the boundaries of their knowledge and experience. Furthermore different elicitation techniques can derive very different responses from similar circumstances and respondents.

In this respect, there was a call for greater integration of new developments in behavioural economics and neurosciences in order to understand better the personal, contextual and other factors that shape preferences and choices. This required bringing together a range of disciplines to strengthen the behavioural, cognitive and psychological aspects of valuation, accompanied by new methods of eliciting values.

Most respondents thought that the design and/or application of valuation methods could be improved and/or extended in some way. Some respondents thought cost and income based valuation methods, such as dose response, defensive expenditure and replacement costs, could be more widely used to assess the impact of environmental change. A number of respondents argued that more could be made of revealed preference methods drawing on observations of actual behaviour, incorporating new capabilities in spatial mapping systems. There were concerns about the inappropriate or unreliable use of Benefit Transfer methods. In this respect there is scope for guidance on the selection, design and use of valuation methods, including tests for the rigour of the methods used and the robustness of the analysis and results.

Respondents alluded to the importance of property rights and entitlements, such as land tenure, water licences, fishing rights as these gave permission or prominence to particular interests and values, and thereby the distribution of benefits arsing from NRES uses. It was noted that property rights for private goods tend to be better defined than those for public goods. Many aspects of unsustainable use of NRES are associated with a failure of entitlement regimes, resulting in negative external impacts, now and into the future. These institutional and distributional aspects of NRES were considered an important component of valuation research. Many values of NRES are grounded in perceptions of entitlement.

A number of respondents were particularly concerned that valuation could by-pass democratic process and the planning and political debate surrounding contemporary NRES issues, such as climate change or biodiversity loss associated with large developments. However, an ecosystems approach, supported by stakeholder participation, could help guard against this.

6.4 Decision support techniques

Respondents reported using a variety of decision support techniques into which estimates of NRES valuation were incorporated. These included Cost:Benefit analysis (CBA), Cost-effectiveness analysis, Econometric (regression based) methods, Life Cycle Analysis, Programming and simulation, and Environmental Accounting. There also appears to be a growing interest in Bayesian simulation, often combined with qualitative scenario analysis.

A range of views were expressed about the overall efficacy of CBA as the dominant decision technique within which NRES valuations are placed. Advocates argued that CBA, not withstanding its shortcomings, was ‘the best decision tool we have’. Furthermore, it was argued, CBA can be integrated with other more qualitative multi-criteria methods. This was seen as a potentially rich area for NRES research. It was noted however that the exchange between the two methodological perspectives has often been one of hostile rather than constructive criticism. There is opportunity to redress this impasse.

6.5 Adequacy of data and knowledge and management of uncertainty

Respondents made wide ranging comments on the adequacy of data and knowledge to support NRES valuation. It was argued that the adequacy and suitability of data for valuation needs to be assessed by environmental and social scientists working together, rather than independently. There is also a need to systematically appraise the rigour of valuation studies and estimates, and guidance on how this might be done.

6.5.1 Environmental sciences

Respondents pointed to a considerable existing body of knowledge, data and evidence regarding NRES. It is not clear, however, until a particular demand is made, whether this capability is adequate for the purpose. But usually there is some existing understanding that can provide a starting point for valuation, from which further needs can be identified.

It was argued, however, that it is important to appreciate the limits that current data and scientific understanding impose. It was deemed important to communicate the degree of confidence in an environmental estimate, and then to judge whether this was acceptable for purpose and possible outcome of valuation, that is some notion of optimum ignorance and the implications of 'getting it wrong'.

A critical point raised was the need to identify the degree of detail, 'granularity' and complexity that is required to feed into valuation process. Natural scientists who engage in valuation studies are aware that they must represent complex and dynamic environmental attributes to non experts in simple accessible, understandable and relevant formats. As one social scientist argued, 'ecologists need to think much more about how the environment is important and valuable to people'; essentially what aspect of the environment provides value. The social scientist needs to frame questions about changes in environmental quality in ways that are meaningful to those whose opinions are sought. All this requires close working from the onset to determine the 'accounting unit of environmental service', framed by both sciences in ways that are valid, robust and meaningful.

Respondents drew attention to gaps in information in natural sciences and the need to improve the understanding and analysis of risk and uncertainty. A number of respondents, both natural and social scientists raised the problems of handling variation in scale, space and time required for valuation studies. A number pointed out that much NRES data relate to the micro scale, collected for specific circumstances in specific time periods. While these data, and associated knowledge, are useful, they may not be entirely suitable at the larger scale in the context of higher level valuations such as catchment scale assessments of flood generation from farm land. Nor may they be suited to considering marginal effects. The greater emphasis on policy relevance will induce a greater degree of integration of scientific data, knowledge and capability.

6.5.2 Social and economic sciences

Some respondents made specific suggestions about what needs to be valued. These included water run off across landscapes, values of aesthetic changes, intrinsic values for biodiversity and heritage, noise, and the impacts associated with climate change. It was argued that we know far too little about how values (in the psychological sense) come about and change. It was argued that the influence of media, lifestyles, peers, own experience, and school curricula on attitudes towards the environment was 'obvious but not well understood'. For some, this called for extending the amount of behavioural and neuroscience research in an attempt to overcome the limitation of partial analyses that investigate but small segments of the 'real world'.

There was a call for ways of improving the robustness of valuation estimates by doing two things: first by improving the way existing methods are used, as referred to above, and second by extending the methods used, especially with regards to enhancing participant knowledge and understanding of the topic of valuation by using more deliberative methods of stakeholder engagement.

Respondents questioned whether the items measured by environmental scientists were suitable indicators for the values sought and whether expert understandings of how the environment works could be transposed for use by social scientists. This requires making a clear link between conditions and processes relevant for the analysis of environmental change, such as the chemical properties of water, and the value of water to different users of water, such as local residents, riverside walkers and anglers.

6.6 Integration of social and environmental sciences

Although most respondents thought that the integration of the science presented some problems, half thought that these were reasonably easy to overcome. It was, in the words of one respondent, "just a matter of getting the social science modellers and the hard scientists together" and that "when this happens, each contributes to the understanding and methods of the other". Barriers to integration could be overcome with "open-mindedness" and "regular communication and planning". Integration "can be done if researchers from different disciplines take a positive approach to multi-disciplinary work". No doubt some degree of compromise might be required in the first instance, as one respondent noted - "more and more biologists are willing to work with economists, and economists have made quite an effort to learn and be patient with biologists". It was interesting to note that many social scientists working in this field came from an agricultural economics tradition, more recently supplemented by those with training in ecological economics.

However, strong views were also aired on the difficulty of achieving the integration needed for valuation research. The interrelationships between natural and social sciences were not always well understood. It could be that there was "lack of interest in what the 'other side' is up to" and that the "rewards" and "incentives for true multi-disciplinary work are not good". Others stated that 'scientific complexity and practical considerations', such as funding, made integration difficult. Some economists were critical of the ability or willingness of natural scientists "to join things up", sometimes preferring to work in very specialist areas, without "engaging with the bigger picture". This perception may arise because scientific research designed to provide detailed understandings of natural systems are now required to support the appraisal of development and policy options working at different temporal and spatial scales. Thus, tensions arise because of mismatching of purposes.

6.7 Primary and secondary data for valuation research

Respondents reported that a wide variety of primary and secondary data is used in valuation research.

6.7.1 Primary data

Primary data include data collected on specific sites with respect to environmental conditions and processes, such as habitat surveys, soil and water qualities, or processes such as soil erosion and surface and ground water flows, air quality, noise levels, and land use and farming practices. Some were collected through site monitoring, some specifically as part of projects and some as part of on going monitoring regimes. It was noted that data are expensive to collect and, other than general monitoring, data collection is often tailored to a particular study such that its application elsewhere can be limited. However, some respondents thought that much more could be made of existing data sets, especially by 'joining them up' and also by reorienting some of the ongoing monitoring regimes to suit new purposes.

Regarding social science data, it is now common to undertake stated preference type surveys as part of large development projects, and it was argued that this should become a requirement for major policy areas. Although primary data were usually collected for specific purposes, steps could be made to make more data and analysis suitable for "benefit transfer". The view was expressed that numbers without context lack meaning and it could be misleading to separate data and insights from their origins.

A common concern was how little was known about how people actually use the environment in Britain, and how this varies according to spatial and demographic factors. This point reinforced a call for revealed preference studies which monitor actual behaviour. It was noted, however, that data on non-use values for the environment are particularly limited and challenging to obtain.

6.7.2 Secondary data

Secondary data includes published survey (house prices, farm business data) and census data or data on published in previous valuation papers, local authority data, visitor numbers and data from government agencies such as Defra. The use of primary data collected by other projects through interviews and focus groups and transferred to new or extended applications was also important. Many physical data were also mentioned, such as data on carbon emissions, fishing catch, biomass production, meteorological data, land cover, soil maps, and air pollution data, and also the use of air-photos, texts on aesthetic appreciation of nature in landscape history, garden history, philosophy, conservation literature, literature in environmental ethics, verbal descriptions, photos, films showing noise levels and traffic movement.

It was felt that there was considerable scope for using secondary data in valuation research, especially drawing on natural science data sets to identify base line and change scenarios, and relevant scientific indicators that could then be 'transposed' into social science applications. In the view of one respondent, it was "a question of understanding what the available data mean, and how to interpret them". However, there were limitations, for example, the most obvious being that the data were not collected for the research in question. Many respondents thought that some data sets were underutilised partly because they had not been integrated and/or offered in accessible ways, such as in GIS format. Some expressed the view that secondary data sets had become expensive to acquire, implying that data on public goods was controlled by private domains. The maintenance and updating of secondary data sets were of concern to some.

6.8 Valuation output data and results

Respondents reported that the findings of valuation studies were communicated in a range of project reports, papers, models, maps, and databases. Most respondents thought the outputs were suitable for use in decision making.

The main users and providers of valuation research were referred to earlier. Practitioner consultants are amongst the main users of valuation methods, using them to make the link between project Environmental Impact Assessments (EIA) and Cost:Benefit Analysis (CBA), for example in the transport and power sectors. Stated preference methods are now widely used, especially on large investment projects which 'can afford' to carry the cost of focussed impact and valuation studies, often targeting particular impacts and stakeholder concerns. Deliberative valuation methods are more common in research and academic applications,

although these are now increasingly used to engage stakeholders in the appraisal of local and regional development strategies.

The perceived range of intended end-users and eventual beneficiaries of valuation research was considerable. Mention was made of the international, national, regional and local government agencies, regulatory bodies, conservation and community organisations, corporate organisations, and other researchers and academicians.

Respondents pointed to examples where their work had informed policy in practice at a range of scales, for example with respect to agri-environment schemes, water resource management, and strategic decisions on transport and energy.

Some expressed concern that the process of valuation could be counterproductive, in so much as unsustainable trade-offs, mitigated by compensation, can be justified when otherwise they would not. There were concerns that, in some cases valuations, promoted by those with vested interests, could by-pass democratic participatory processes that might take a broader and different view of preferences. It was noted that the more deliberative forms of valuation could counter this possibility, although these too were liable to bias unless steps are taken to guard against it.

6.9 Handling Uncertainty

Regarding the treatment of uncertainty in valuation studies, most respondents stated that they dealt with this through a combination of statistical methods, such as specification of confidence intervals, error terms, and sensitivity analysis. Some advocated the increased use of simulation and risk modelling to mimic the observed variation and random effects in natural systems. Risk based methods such as Monte Carlo Simulation and Bayesian probability methods were advocated by some. Scenario analysis seems to be most common technique for handling uncertainty, in both natural and social systems. The availability of low-cost software for risk modelling should, it was argued, enable the explicit treatment of risks and uncertainty in the analysis and presentation of results. In recent years, capability in the modelling and communication of risk and uncertainty has increased considerably. This is an important area for research.

6.10 Future Priorities

Respondents proposed a number of actions to extend and improve the quality of valuation research. They suggested that consideration should be given to the following aspects:

The ecosystems framework should be used to help set priorities for valuation by identifying the critical links between NRES and social welfare, defined at the relevant scale. Identifying key relationships between NRES and major policy areas would also help guide valuation research.

Existing data sets and modelling capability should be joined up and made available to support valuation research, such as, for example, soils and hydrological data at the catchment scale. A greater depth of understanding on uncertainty, thresholds and resilience in natural systems is urgently required, including guidance on how this should inform the derivation of NRES values.

Regarding methods, there should be more integration between quantitative and qualitative methods, especially combining CBA with multi-criteria and qualitative, narrative based assessments of values and preferences.

More attention was required to enhance the robustness of stated preference methods, especially understanding how and why people make decisions, and how choices vary according to factors not included in choice sets, such as cultural, personal and socio-economic factors.

New developments in neuroscience and psychology should be incorporated into valuation studies in order better to understand attitudes and behaviour towards NRES and to make choices 'more realistic'. More use should be made of deliberative methods such as interactive workshops, 'learning schools', citizens' juries, and techniques of visualisation to enable participants to construct better understandings of hypothetical choices. Aspects of evolutionary science can be drawn on to understand the way values change over time and space in response to a variety of factors.

More emphasis should be placed on revealed preferences, that is, on recording and understanding actual behaviour and use of the environment. There is need for a better understanding of how people actually make choices on environmental quality and how values are actually derived.

The use of BT techniques needs scrutiny, improvement and guidance. Consideration should be given to producing an archive of BT estimates, specifying more precisely the underlying value functions in ways that facilitate and justify BT.

There is a need, using the ecosystems framework, to explicitly link stakeholder values with property rights and entitlements in order to explain how institutional arrangements shape the use of NRES, with consequences for sustainability and social welfare.

There is a critical need for best practice guidance on the use of valuation studies for non-academic practitioners involved in project and policy appraisal. There is also a need to systematically evaluate the rigour of valuation studies and estimates, and provide guidance on how this might be done.

There is a need to enhance incentive and reward to those working in integrated valuation research, partly through funding, career development, enhancing networking and research media that recognise achievement in multi-disciplinary research.

6.11 Justification for Research on NRES Valuation

Respondents argued that valuation research had an essential role to play in the future management of NRES, especially regarding the valuation of public goods and the formulation and implementation of policy to improve the sustainability of NRES. They saw valuation as a means of securing the future of vulnerable environmental qualities and systems - by demonstrating their value to people.

All respondents, in various ways, expressed the view that if NERC wishes to ensure that its research has policy relevance, it must undertake valuation research that explicitly considers the relationship between environmental change and change in social welfare. It should, in the view of some, identify those areas of natural sciences (NRES) research that, once combined

with valuation studies, will enhance social well-being while protecting the integrity of living systems as a whole.

6.12 Options for NERC Engagement in NRES Valuation Research

During personal interviews with 10 leading researchers in NRES research, 9 of whom were familiar with NERC's research agenda, discussions were held on possible options for delivering NERC engagement in NRES valuation research. Not surprisingly, given the research interests of the respondents, there was consensus that this was a valid area for NERC activity and sponsorship. This was essential, it was argued, if NERC is to make the link between NRES and social and economic welfare and to ensure the policy relevance of its research programmes. Two main issues arose, namely: what the research focus of this engagement should be, and how it might best be delivered.

With respect to the focus of NERC activity in NRES valuation, views varied on the boundary and scope, although most thought that the ecosystems framework provided, for the most part, a useful approach within which to define the approach to valuation research. Views varied on the detailed topics of research, some arguing that NERC should, given limited funding, confine itself to mainly economic monetisation of NRES benefits and costs, rather than the further development of new areas associated with behavioural, psychological and neuro sciences. These might, it was argued be left to other research providers, especially ESRC. Others, however, argued strongly that this should not be the case, that it was these new areas of research into deliberative and participatory that methods offered new insights and greatest potential gain. It was argued that NERC should be actively promoting their development through funding. All thought that funding should support interdisciplinary working on NRES valuation. Some of the priorities for research were alluded to above.

With respect to delivery options for NERC NRES valuation research, a number of broad options were identified, as follows

(i) Carry on as at present in a largely responsive mode to expressions of interest in NRES valuation

(ii) Fund networks of institutes and individuals, including sponsorship of collaborations, that bring together different disciplines on a semi ad hoc basis

(iii) Establish a capability in social sciences within NERC institutes

(iv) Fund multi-disciplinary Research Centres, operated by non-NERC research providers.

(v) Fund long-term (4 to 5 year) collaborative research programmes that focus on NRES valuation in strategically relevant policy areas.

Respondents commented on the relative advantages of these approaches. Approach (i) was thought inappropriate if NERC wishes to promote its policy relevance. Approach (ii) was thought capable of supporting small scale initiatives but will not effect a major change in activity. Approach (iii) was deemed not to have worked when this was tried previously because social science, mainly junior, staff tend to be marginalised and unsupported. Approach (iv) can, it was argued, help to build and maintain capacity in multi-disciplinary and integrated working providing steps are taken avoid exclusivity and a risk that dynamism levels off over time. There was considerable support for approach (v), with long-term funding of projects that brought researchers from different sciences and applications together. The RELU programme was referred to as an exemplar that demonstrated success in the integration of the sciences in ways that appealed to a range of stakeholders, including policy

makers. It was noted that such projects often took three years of multi-disciplinary working together to develop the required understanding amongst scientists of different persuasions. Such projects could, it was argued also further developed networks. A number of respondents also pointed to the commitment and strategic capacity that already existed and could be further enhanced in a number of multi-disciplinary groups in universities and other research providers.

Chapter 7 : Conclusions and Recommendations

This chapter draws together the main conclusions against the study objectives and makes recommendations with respect to NERC strategy towards NRES Research.

7.1 Overview

The Natural Environmental Research Council (NERC) identified the need to review the existing evidence base to support its strategic priorities in its Science Theme for the **S**ustainable **U**se of **N**atural **R**esources (SUNR), particularly with respect to the valuation of natural resources and ecosystem services (NRES).

In this context, the broad purpose of this scoping study seeks to inform NERC strategies on the valuation of NRES, thereby enhancing the Council's potential contribution to sustainable development.

The study aims to produce a 'state of the science' review of NRES valuation in terms of what exists, what is being done, how well it works and perceptions of likely future needs amongst the research community.

7.2 Approach

A variety of methods were used to assess the current state of valuation with respect to NRES, these included a search of academic literature, email questionnaires, and semi-structured interviews.

A number of dedicated web-based research inventories and project sites were reviewed that facilitate information and knowledge exchange on NRES valuation, including data, methods and results. Responses to an email questionnaire survey were obtained from 35 researchers involved in NRES valuation, followed up by telephone interviews with 10 researchers, 5 of whom had replied to earlier correspondence and 5 of whom were newly contacted. Thus, about 40 respondents were involved in total. Results from formal questionnaires were stored electronically to enable systematic retrieval.

It transpired that a formal review of the treatment of risk and uncertainty in NRES valuation research was not possible within the resources available, but this was a topic covered during the survey of researchers.

7.3 Conclusions

Conclusions are made against the main objectives of the study

7.3.1 Main types and applications of NRES valuation research

From a human perspective, the term value implies something that is good and pleasurable. This view of value is largely 'instrumental' in that something is good because of the benefits it bestows to people. Valuation is the process by which values for goods and services are obtained. An obvious basis for value is that given by the willingness to pay and receive payments for items exchanged in market transactions. However, many of the flows of goods and services associated with natural resources are non–market, public goods for which prices and monetary values are more difficult, and in some cases impossible, to obtain.

A review of academic and grey literature showed that a range of techniques has been developed and used for the valuation of NRES. Techniques fall into two broad types. One type involves economic methods that derive monetary values by exploring the impact of environmental change on incomes or costs, or by constructing surrogate markets to determine willingness to pay by citizens for environmental goods and services. The other type involves a range of deliberative/participatory methods which seek to elicit values and preferences for environmental goods and services through discourse and knowledge exchange with citizens. Deliberative methods have been developed partly in an attempt to overcome the perceived limitations of economic valuation methods.

The review confirmed the potential advantage of adopting ecosystems framework to represent the diversity of service flows and a basis for valuation. It was noted however, that the valuation of NRES is made difficult by inherent uncertainties associated with the response of ecosystems to anthropogenic pressures. These can generate gradual or catastrophic failure in ecosystems, with consequences for human welfare. Explicitly building in allowance for, and communicating the inherent uncertainty associated with, ecosystem dynamics is an important element of NRES valuation.

With respect to research domains, the review of electronic databases showed that the most frequently occurring keyword descriptors associated with NRES valuation tend to be land-based, concerned with “land”, “forests”, “agriculture” and “landscapes”, followed by those referring to “water” and “wetlands”. Energy is relatively under-researched as a NRES topic. NRES valuation research is dominated by the USA, but there has been a steady growth in capacity in the UK and Europe as a whole.

7.3.2 Perceived capacity in NRES valuation

The vast majority of valuation research uses economic, monetisation valuation methods, especially using contingent valuation. The most frequently used decision support method used in valuation research is Cost:Benefit Analysis. More recently the reported use of deliberative methods has grown, typically associated with large funded multi-agency research programmes.

A review of NRES-related projects showed that the main types and applications of valuation research are heavily focussed around the concept of ecosystem services, integrated biophysical modelling, interdisciplinary approaches, and stakeholder engagement. Most are developing data and methods which are potentially relevant for policy management. Some projects are particularly oriented towards end-user support. The Environmental Valuation Reference Inventory (EVRI), for example, provides a classified information base that supports the transfer of primary benefit estimates to secondary applications. In this respect, there is a growing international capacity in NRES valuation that contributes to the design, appraisal, implementation and evaluation of policy interventions. There is scope to enhance this in the UK.

Most researchers engaged in NRES research reported that they thought methods and data were, for the most part, suitable for the purposes of NRES research and outcomes. There was a call for greater integration of data sets to support integrated modelling, especially in GIS interactive format. There was growing interest and capability in the integration of quantitative and qualitative methods, combining for example Cost:Benefit Analysis, with participatory methods, supported by visualisation techniques.

7.3.3 Stakeholder interest in NRES valuation

There is heightened awareness of the importance and potential instability of the relationship between natural resources and human welfare, evident in recent scientific reviews such as IPCC, the Millennium Ecosystem Assessment and the Stern Review. As the leading UK research body in natural sciences, NERC's strategic science theme on the Sustainable Use of Natural Resources includes a commitment to valuing environmental services.

A review of stakeholder interests drawn from reviews of literature projects and correspondence with senior researchers show a wide range of interest in the topic, incorporating international, national and local government and development agencies, regulatory organisations, non-government organisations, insurance and finance organisations, corporate bodies and other researchers.

Most of the interest in the use of NRES valuation results is associated with the appraisal of project development and/or policy options. This interest tends to find expression in research sponsorship and, in this respect, key interests line up with influence on the research agenda.

It is true that to date, greatest interest and influence has been expressed through the sponsorship of economic appraisals. There are signs that this is changing in favour of more deliberative participatory methods, especially through the larger scale integrated research projects. International and national development agencies are also showing much greater interest in NRES valuation reflecting a greater commitment to citizen participation and policies that promote social and environmental, as well as economic outcomes.

7.3.4 Main challenges with respect to data, methods and expertise

Most of the surveyed respondents involved in NRES valuation research reported that the integration of the underlying science presented some particular problems although half of these thought that these could be overcome relatively easily. It was considered that much progress had been made in recent years in interdisciplinary working necessary to support NRES valuation. Progress had been made drawing on funding associated with international and national funding programmes, such as EU projects which included non-EU participants and RELU type programmes. There remained some challenges to ensure that incentives, rewards and support were available for those who engaged in multi-disciplinary research, especially younger scientists.

The majority of respondents thought that existing data and methods were broadly fit for purpose, but there was scope for improving coverage and quality to provide more complete and robust estimates of value. There was some concern about quality assurance in NRES valuation and a need was identified for best practice guidance on the use and scrutiny of valuation methods for project and policy appraisal.

For the most part, researchers thought that the ecosystems framework helped to construct an understandable and potentially comprehensive approach for the value of natural resources.

Review of literature and correspondence with researchers identified priorities for future development of capacity in NRES valuation. These included:

- improved integration of existing data sets and of quantitative and qualitative valuation methods,

- continued development of integrated biophysical and socio-economic modelling of NRES at relevant spatial and temporal scales, addressing key areas of risk and uncertainty,
- improved quality control in the use of valuation methods, especially stated preference methods and benefit transfer,
- improved understanding of values through the use of deliberative participatory methods,
- more use of direct observations of actual behaviour, and
- improved understanding of the role of property rights and entitlements.

It was perhaps not surprising that those involved in NRES valuation considered it to be an essential component of a research strategy for the sustainable use of natural resources, and an essential component of policy relevant research. They saw that is was a valid area for funding for a national research body such as NERC. There was considerable support for a strategy that provided long-term funding of relatively large projects that brought researchers from different sciences and applications together. They cited projects of this kind that had yielded success in terms of capacity building and research contribution.

7.4 Recommendations

Following this scoping study, a number of recommendations can be made for NERC regarding NRES valuation research as part of its support to the SUNR Science Theme. It is recommended that NERC should explore in more detail:

- The potential feasibility and advantage of adopting the ecosystems functions and services framework as a basis for guiding NRES valuation research that explicitly links the health and integrity of natural resources with the well-being of people and communities.

- The priority areas for future development identified in the course of this study with a view to targeting key areas of support to the NRES valuation research community, including the balance between and the integration of economic and non-economic methods.

- How best to record, maintain, integrate and make accessible natural science (and related) data sets and asset inventories which can be used in NRES valuation research, including support to existing web-based providers of information services.

- The need for, and best way of providing, guidance on best practice and quality assurance of NRES valuation research.

- Investment options for NRES valuation research, including the potential for long-term funding of collaborative, capacity building research projects organised under a Thematic Research programme which explicitly seeks to link the management of NRES with social well-being.

- How incentives, rewards and support can be marshalled to encourage innovative interdisciplinary research of the kind needed in NRES valuation, especially for young researchers.

- How, in the light of the observations made here, NERC Science Strategy can become more policy relevant, possibly setting up an Advisory Panel that manages the interface between NERC science and policy, and between NERC and other UK Research Councils.

7.5 Epilogue

It is clear that NERC research in the area of valuation has much to offer in the strategic management of Natural Resources and Environmental Services, informing decisions on how people and communities can continue to prosper without irreversibly damaging the environment that supports them.

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Appendices

Appendix A : Perspectives on Valuation - The results of surveys of respondents involved in NRES valuation

This Appendix reports the findings of surveys of respondents to elicit views on the current state of valuation science and priorities for the future.

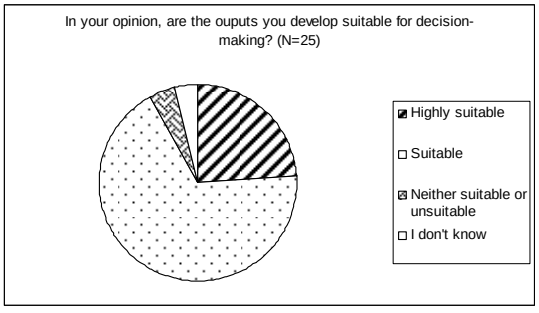
It draws on 24 responses to a 'long' questionnaire which covered both generic questions and specific questions on selected areas of work, 10 responses to a short questionnaire which sought views on selected aspects of valuation work, notably on issues relating to the suitability of data and methods for valuation and the challenges of integration. It also draws on 10 personal telephone interviews which further explored data and methodological challenges as well as priorities for future research.

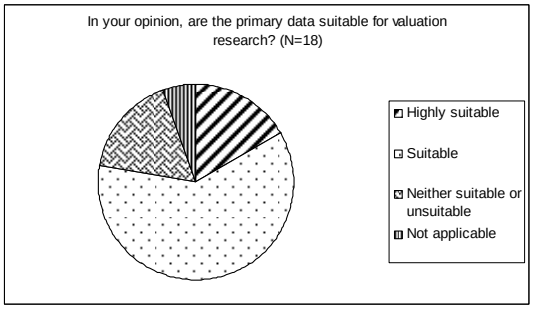
All respondents were initially identified through the reviews of published work. It is noted that the commentary here reflect the interests and perspectives of the respondents which may to varying degrees reflect the broader church of opinion amongst those engaged in valuation.

The results are reported in the following sequence. The main areas of application and the drivers for valuation in terms of target needs and outcomes are covered, together with the main methods employed and the extent to which these methods are deemed fit for purpose. Views are reported on the availability and suitability of data to support NRES valuation, gaps arising and ways of handling uncertainty associated with data and methods. Respondent views on the perceived contribution of valuation studies to promoting the sustainable management of natural resources are also reported, together with the extent to which researchers interacted with other interested parties. The reporting below takes the perspective of the respondents throughout, unless other wise stated.

Perceptions of Suitability of Valuation data and Methods

Figure A. 1 shows responses to questions by those engaged in Natural Resources and related Ecosystem Services (NRES) research about the suitability of data, methods and procedures for NRES valuation studies. Most respondents thought that data sources and scientific understanding were suitable for the purposes of valuation research, although increased scientific knowledge tended to create further "known unknowns". The great majority, perhaps not surprisingly thought their valuation research was suitable for decision support. Although 90% of respondents identified some problems and challenges with the integration of the sciences required for valuation, half of these thought the problems could be easily overcome. The reasons for their assessments are discussed below.





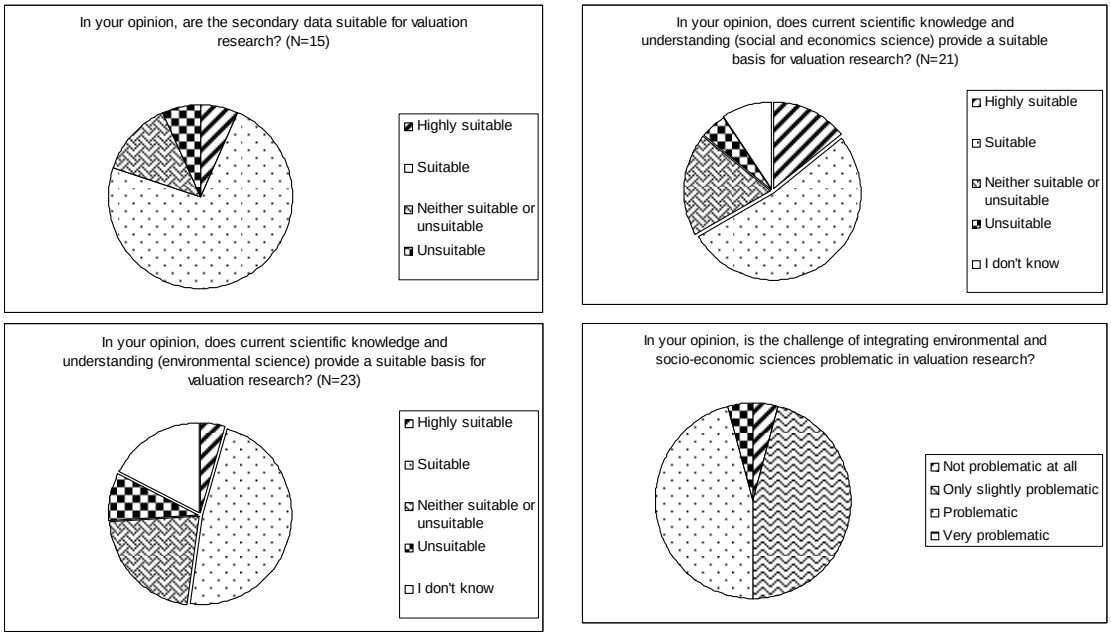


Figure A. 1. Respondent Views on the Suitability of Valuation Data and Processes

Ecosystem services valued, and drivers of environmental concern

The majority of respondents said they had researched within the NRES areas of "land", "water" and "living systems", although some had specific interest in selected economic sectors such as transport, energy or agriculture. Their interests cover a range of ecosystem functions and services.

A wide range of reasons were given for concerns that prompted the research, from "concern at imminent environmental catastrophe" and "concern for future generations" to "biodiversity loss", "land use change", and attempts to evaluate policy impacts. In all cases, the cause of concern could be linked to some form of human induced impact on the environment, whether intended (exploitation of peat) or unintended (biodiversity loss), with the research used as a means of measuring the net effect on human welfare. It was apparent, judging by the interest of research sponsoring agencies, that much of the valuation research was promoted by policy questions such as how best to balance biodiversity and farming objectives, or project development proposals associated with, for example, alternative energy supplies.

Practitioner consultants are main users of valuation methods, using them to make the link between EIA and Cost benefit analysis (CBA), for example in the transport and power sectors. Contingent Valuation and to a lesser extent choice experiments are now widely used, especially on large investment projects which 'can afford' to carry the cost of focussed impact and valuation studies, often targeting particular impacts and stakeholder concerns. CV studies here have almost become a prerequisite for feasibility and project design. There is some concern amongst academic communities about the rigour with which commercially driven studies are applied and the results used.

It was universally argued that if NRES is to be policy relevant, it must engage in valuation. It was clear that respondents clearly see an important and critical link between changes in NRES and social welfare, although different disciplines used different words and constructs to express this understanding. It was a wish to explore and communicate this relationship as a

means of promoting some view about improved sustainability that seemed to distinguish those natural scientists that wished to engage in the valuation process, compared to those that did not. The view was expressed by a number of respondents that most natural scientists are motivated to research fundamental relationships leaving others to interpret research findings for other purposes.

Valuation methods

Without exception, respondents found it easy to draw distinctions between **evaluation** of the kind used to identify and quantify emissions and impacts in the context of Environmental Impact Assessment, and **valuation** of the kind associated with putting monetary values and relative social preferences on impacts associated with environmental change. It is the latter that is of concern here. Most natural scientist were historically familiar with the former type but reported that their engagement with the latter had increased, typically over the last 5 years or so.

The respondents reported that they had, between them, used a variety of methods (BOX A). These included cost and income based methods such as replacement cost, dose response based bio-economic modelling, actual expenditure, defensive expenditure, loss of production, damage costs, cost of substitutes, and regression-based econometric analysis on observed costs and benefits. Stated preference methods included contingent valuation and choice experiments. Other Stated preference techniques such as Market methods. Qualitative methods, such as "thought" and workshops were mentioned and other approaches included 3-D Computer visualisation, scoring, weighting and energy analysis methods were also mentioned. Revealed preference methods such as hedonic pricing, travel costs and observed 'market' behaviour and participation were used. The majority of respondents suggested that the methods used were at least "suitable" for the purpose of valuation.

Respondents made the clear distinction between these methods and saw them as fit for different purposes, reflecting also the available data and the phenomenon to be valued. There was a clear distinction between stated and revealed preference methods in terms of suitability for different purposes. Regarding stated preference methods, some practitioner respondents thought that the techniques were well tried and tested and robust, others thought that they were overused or used inappropriately with limited quality control.

Academicians considered that there was much to be done to improve the reliability of SP methods, especially with respect to better framing of the environmental attributes to be valued, and a better appreciation of the factors that determine responses to WTP questions and choice sets.

There is concern that responses can be manipulated by the framing and context of the valuation choices, and much more needs to be done to facilitate consistency in questions and answers. Some research shows that answers are 'all over everywhere' and yet the reasons why often remain unclear. Furthermore different elicitation techniques can derive very different responses from similar circumstances and respondents.

There was a call for greater integration of new development in behavioural economics and neurosciences in order to understand better the personal, contextual and other factors that shape preferences and choices, thus relaxing the assumption that decisions are purely based on a utilitarian view of the attributes and choices that people are faced with. In this respect,

there was a call for new integrated approaches, drawing together a range of disciplines, especially strengthening the behavioural, cognitive and psychological aspects of valuation.

There was a need, it was suggested, to directly address the known limitations of conventional stated preference methods. These techniques become unreliable when people are asked questions that go beyond the boundaries of their knowledge and experience. The potential of learning schools, interactive workshops, field trips, citizen juries, and critically it was thought, visualisation methods were seen as ways of overcoming the limits and bias of conventions methods. But, these required more time and expense.

A number of respondents argued that more could be made of revealed preference methods. These, it was argued, are more robust because they are based on actual behaviour and less liable to respondent bias. It was strongly argued that not enough was known about the way that NRES are actually used, and that observation of actual behaviour was a rich area for valuation studies. It was suggested that the UK was particularly lacking, compared to the USA for example, in this respect. It was also argued that there was considerable scope to combine RP methods with GIS methods, and to better integrate RP techniques to focus on particular aspects of NRES. Examples quoted included the use of hedonic methods to explore the link between house prices and recreational values.

It was also argued that more could be done using cost and income based valuation methods, such as dose response, defensive expenditure and replacement costs. While economists recognise these do not give complete measures of the value of changes in environmental quality, they are often more accessible and understandable, and can provide first order estimates of the value of non market goods.

BOX A: Selected views on valuation methods

- Choice experiments are a well tested means of eliciting consumer preferences
- Hedonic methods have a clear theoretical foundation and avoid double counting.
- Workshops allow information provision, discussion and interpretation of information. Our research (so far) suggests more appropriate and stable choice making is made in workshops than individual interviews
- The choice experiment was good in that it elicited robust relative values across the 4 ecosystem services. The contingent valuation method provided robust values for biodiversity protection as a whole.
- Qualitative methods are extremely useful to improve our understanding of what people value about a certain resource
- The question being asked, the availability of existing data, the size of the policy change, as well as time and budget for the project usually determine the appropriate valuation technique or techniques. At this point, the various techniques are reasonably well understood. If a project is well funded and has sufficient time most techniques (if appropriate for the task at hand) can be reliably implemented.

However, there were some cautions about the process and expectations of valuation. Some argued that there was a limit to how many more CV studies could be usefully done. Some argued that cost effectiveness analysis might be a more appropriate tool than benefit assessment. Here the environmental target is set and the challenge is how to achieve it at least cost. This techniques does not, of course indicate whether there is a change in net social welfare.

A number of respondents were particularly concerned that valuation could by-pass democratic process and the planning and political debate surrounding contemporary NRES issues, such as climate change or biodiversity loss associated with large development. (BOX B)

BOX B: Selected criticism of valuation research.

- I question the need to do valuation research of the sort that is currently again fashionable. This is a circular and cyclical fad, driven, in my personal opinion by a misplaced faith in the market and the value of classical economics in approaching and assessing environmental resources. I think it is a dangerous distraction from effective resource planning, based on assessments of what we have, both in natural and cultural environmental resources.
- I am generally critical of valuation studies. I favour the political process and the need to make explicit and reasoned qualitative judgements, over approaches which attempt to provide 'objective' monetary or other quantitative indices of value but which necessarily present an objectivity which is spurious and compromised, as a result of the assumptions and value-judgements embedded in the methodologies applied. I have used alternative approaches within research which have focused upon capacity and consensus-building in decision-making, through which values can be expressed in a variety of ways and the search is for mutual understanding and common ways forward, rather than quantification and trade-offs. Neither approach is perfect, but I am more philosophically and scientifically comfortable with the qualitative one.
- Mindless application of discounting protocols is the most serious threat to the survival of humanity.

Users of valuation techniques are aware of their shortcomings some of which, they thought, can be addressed by careful application and interpretation of results, sensitivity analysis and associated critique of data and methods (BOX C). Techniques such as CV were liable to well know respondent bias. One respondent suggested that whilst the potential limitations of valuation techniques are known, problems due to pressure to reduce the cost of valuation research in short-term under-funded projects, which inevitably produced unreliable results, which were then blamed on the valuation techniques. Understanding the appropriate precision required for the decision of interest was needed, although it recognised this may not be known beforehand for new topic areas.

BOX C: Selected comments on the practical use of valuation methods

- The major issue in terms of improving valuation methods revolves around reducing the cost and skills necessary to implement them. Quick/under funded projects continue to produce unreliable results that are often later blamed on particular valuation techniques. Crucial to the successful implementation of non-market valuation is a determination of how much precision in the estimates is needed to help make the decision of interest.
- While valuation techniques can always be improved, the large issue is often a failure to understand why different techniques give (and should give) different answers. With respect to their application to specific topic areas, there is often a steep learning curve until the major implementation problems are resolved. These lessons are often transferable to studies involving similar resources and hence a government agency that deals with a sequence of related valuation questions should seek to build up a stock of subject area specific knowledge and experts.

- Concerns remain over trying to represent complex environmental issues in the context of a short stated preference survey
- No environmental valuation method is ideal. Should always be accompanied by text/analysis that highlights the problems of the method. Valuation estimates should be subject to extensive sensitivity analysis within cost-benefit or other decision support tools
- The valuation methods are okay, though subject to lack of certainty.
- Wide range of damage cost estimates leads to wide range for estimated values of benefits (sensitivity analysis useful)
- I do small-scale experiments designed to highlight weaknesses in contingent valuation, especially in relation to passive use value.
- In my research, I frequently found WTP to be hardly related to the preferences for the goods and services assessed through other measures (e.g., ratings). Whereas these ratings seemed to be well explainable with plausible conceptual models, WTP was not. I therefore doubt the (theoretical) validity and meaningfulness of WTP amounts.
- I analyse and re-analyse data to show problems due to collinearity and complexity of functional form, especially in relation to aesthetic values.
- Travel cost method assumes travel is a pure cost when empirically one can show that frequently it is a benefit in itself and the ratio of benefit to cost in any journey to any site is likely to vary significantly.

Most respondents thoughts that the design and/or application of valuation methods could be improved and/or extended (BOX D). Some respondents made extensive suggestions regarding the improved use of valuation techniques. For some, it was clear that valuation is a developing field and that effort was needed to make best use of valuation methods, with more attention to benchmarking of good practice. In this respect there is scope for guidance on the selection, design and use of valuation methods, including tests for the rigour of the methods used and the robustness of the analysis and results.

Most respondents had views about the use of benefit transfer (BT) methods, and their relative advantages and disadvantages. More could be done to specifically build up an archive of estimates that would lend themselves to benefit transfer, particularly specifying more precisely the underlying value functions in ways that facilitate and justify BT.

More than one respondents warned against the “mindless application of discounting” when the main challenge was to derive reliable estimates of benefits and costs in the first place There was a general call for careful sensitivity analysis and the need to make the “limitations of methods explicit”. A number of respondents alluded to the dangers of forcing monetary values where none reliably existed: as one reported, “any impacts that cannot be monetised should be highlighted”.

BOX D: Selected suggestions on improved application of valuation methods

- Of course the methods could be improved, especially for valuing biodiversity.
- Valuation research is wide open and needs to go well beyond application of standard techniques. It needs to take into account recent psychological research on happiness and quality of life. It needs to be much better integrated with modelling of the biophysical environment.
- Contingent Valuation (and other Stated Preference Approaches) has a wide range of applications whereas the Revealed Preference Approaches are more limited in terms

of applications. The valuation methods should continue to go through continuous improvements, and every new survey should be combined with methodological tests.

- The validity of Stated Preference methods, especially the non-use values, should be further tested; through comparison of hypothetical and actual willingness-to-pay. Also, there is an even larger need for improvement of benefit transfer/value transfer techniques, as there is often no time nor money to do new primary valuation studies, and e.g. benefits of new environmental policies are assessed through benefit transfer techniques.
- More research should be conducted on the transfer errors of different transfer techniques (Unit value transfer, value function transfer and meta-analysis), national and international transfers, and also on temporal transfers. The level of "acceptable" transfer errors of different policy uses of environmental values should be understood (CBA, environmental charges, Green national accounting and green accounting at the firm level, and Natural Resource Damage Assessments - cf. EUs Environmental Liability Directive)
- For some services for which people are aware (i.e. recreation, provisioning services) current valuation techniques are appropriate. For other services we need valuation techniques that are not tied directly to preferences and perceptions of the general public (i.e. avoided cost, energy analysis, production functions)

Decision support techniques

Respondents reported using of a variety of decision support techniques into which estimates of NRES valuation were incorporated. Thee included Cost–benefit analysis, Cost-effectiveness analysis, Econometric (regression based) methods, Life Cycle Analysis, Programming and simulation, and Environmental Accounting. There appears to be a growing interest in Bayesian simulation, often combined with qualitative scenario analysis (Box E).

These decision support techniques were considered to be suitable or very suitable and no responses were obtained to suggest that they were not. Respondents remarked that it was important to select techniques that were suited to purpose, data and context - “various methods could be used and that choice must be related to the type of issue and investigation.”

A range of views were expressed about the overall efficacy of CBA as the dominant decision technique within which NRES valuations are placed. Advocates argued that CBA, not withstanding its shortcomings, was ‘the best decision tool we have’. Some of these, shortcomings it is argued can, and have been, overcome by modifying assumptions and coverage of cost: benefit items explicitly to include NRES and other values. Furthermore, it was argued CBA can be integrated with other more qualitative multi-criteria methods. There was considerable scope for further developing this integration.

Others argued that monetary valuation and CBA cannot adequately handle the full social value of NRES and that there was need for new development in qualitative, typically discursive analysis which sought meanings rather then numbers. Some argue that these two perspectives were not necessarily incompatible. There seems to be scope for bringing these two camps together to explore the benefits of a combined approach. A number of respondents argued that the exchange between the two methodological perspectives has bordered on hostile rather than constructive criticism.

Selected comments on the choice of decision techniques are given in BOX E.

BOX E: Selected comments on the choice and use decision support techniques

- CBA has the best chance of telling us what we want to know.
- CBA It is within the cost–benefit analysis framework that the implications of discounting are most starkly shown.
- Given that decisions have to be taken, these (CBA and cost-effectiveness) are the best on offer.
- Choice modelling methods, part of the broad family of econometric techniques, are able to exploit theories of consumer choice behaviour to estimate the willingness to pay of consumers to achieve environmental improvements
- Econometric methods have to be applied based on a clear understanding of underlying economic and statistical theory and carefully done.
- Programming and simulation enable long-term future consequences of supply/demand interaction to be presented
- Bayesian simulation can show the implications of lack of certainty for future values.
- No single technique addresses all issues/questions. Some issues are less accessible to study than others, particularly those with diffuse and indirect effects.
- Decision support techniques have been often applied to specific issues/environmental features or sites, but holistic approaches that integrate these techniques for whole ecosystems are not well developed.

Adequacy of data and knowledge and management of uncertainty

Respondents made wide ranging comments on the adequacy of data and knowledge to support NRES valuation. Some comments focussed on specific gaps in the data for specific areas of research. Others were more general or philosophical in nature, tending to focus on how, in their view, valuation research should be applied, particularly to reduce uncertainty. One important message from respondents is that the adequacy and suitability of data for valuation needs to be assessed by environmental and social scientists working together, rather than independently.

Environmental sciences

The main initial response by the natural science community is that there is never enough data to observe and adequately explain natural phenomena, processes and the dynamics of change. This is understandable given obvious gaps in knowledge and understanding. The issue is whether there is enough information for valuation. There was general convergence of views on this aspect. It was agreed that there was a considerable body of knowledge, data and evidence regarding NRES that could be drawn on. It is not clear, however, until a particular demand is made, whether the scientific knowledge and data is adequate for the purpose. But usually there is some understanding that can provide a basis for engagement.

It was argued, however, that it was important to appreciate the limits that data and scientific understanding impose. Whether the environmental science is adequate or not, depended on the possible consequences of getting the answer wrong. So, it was argued, that it was important to communicate the degree of confidence in an environmental estimate, and then to judge whether this was acceptable in terms of the purpose and possible outcome of valuation, i.e. whether getting it wrong would have a significant effect on decisions and ultimately on social welfare.

A critical point raised was the need to identify the degree of detail, 'granularity' and complexity that is required to feed into valuation process. Natural scientists who engage in

valuation studies are aware that they must represent complex and dynamic environmental attributes to non-experts in simple accessible, understandable and relevant formats. At the same time, there is a need to communicate uncertainty where this is perceived to be important. Respondents noted that some scientists find this difficult and somewhat compromising, such that engaging in valuation is likely to involve self-selection.

A particularly salient point was raised without prompting by environmental scientists and social scientists during the personal interviews. One social scientist argued that 'ecologists need to think much more about how the environment is important and valuable to people'; essentially what aspect of the environment provides value. This then needs to shape what is measured. There may be a concern for example about water quality, measured in terms of biological or chemical oxygen demand. But as far as people are concerned it is not water quality per se, but angling potential that is important. Environmental scientists then collect evidence on the topic of concern, for example, about the causes of changes in water quality as this affects a particular item of interest, such as fishing. The social scientist then, for example, frames the valuation questionnaire on water quality with respect to fishing potential. These linkages, it was argued, need to be made between the two sciences.

One natural scientist made a similar argument suggesting that natural scientists should work with social scientists to identify the unit of (ecosystem) service that is of interest to particular stakeholders, for example fruit farmers. It is then appropriate for natural scientist to work backwards down the ecological supply chain to determine how this service is, or can be, delivered. This process identifies the need for data and knowledge to support valuation. The case of beneficial insects such as bees is a case in point. Another example referred to the creation of valued rural landscapes feature such as species rich meadows. The detailed composition of these and the environmental conditions required to supply them, varies according to location. But the same principles are involved in deciding the unit of service and the best environmentally practical and efficient means of delivery. There are some risks in this approach, however, in so much as complex interactions in very dynamic systems result in unintended and unforeseen effects, especially those associated with thresholds and potential tipping points.

Most of the suggestions made regarding natural science data focussed on improving understanding of scientific processes, particularly in response to anthropocentric change, linked to the area of valuation research of the respondent. One respondent stated that some topics of valuation, such as landscape, were extremely complex phenomenon, existing at a number of different scales, combining both natural and cultural systems. Such resources needed to be understood in an integrated way, but defining a system was difficult and hampered by lack of data on key components, such as linear features. Many suggestions were linked to understanding how climate change would affect the environment.

Respondents drew attention to gaps in information in natural sciences and the need to improve the understanding and analysis of risk and uncertainty (BOX F). In some cases, uncertainties were high because data and knowledge had been acquired for purposes other than valuation and policy related analysis. Much existing data, though useful, might not be suited to the analysis of marginal changes associated with new challenges, such as climate change, or some policy intervention on water quality. Lack of data on environmental thresholds and tipping points was referred to, justifying a precautionary approach.

BOX F: selected comments on uncertainties in environmental science for valuation

- There are gaps in terms of the more precise detail such as thresholds etc
- In general there is a need for better understanding of ecosystem functions and processes, and where the tipping point may be.
- There are many uncertainties regarding the flow of ecosystem services from a given area, which in turn means that valuation of the benefits cannot be undertaken.
- The impacts of changes in climate on the ecosystems providing the goods and services. The indirect effects that might occur due to changes in ecosystems.
- The uncertainties associated with climate change and incorporating the very long-term are major areas where understanding needs improvement.
- Scientific understanding of the physical environment is typically lacking. Often baseline information is missing.
- How land use choice affects water flow on the landscape remains unclear , (especially at the catchment scale)
- Foliage and wood decay processes; forest soil fluxes; future climate change impacts on tree growth and species suitability.
- Consequences of economic activity and land use change for greenhouse emissions and climate change, and hydrological effects, and biodiversity.
- impact upon health; probability of risks
- The impact of the natural environment on wider social and economic development
- Landscape is a complex phenomenon, that exists at a number of spatial scales, and that is best understood as an integrating concept, that combines both the natural and culturally modified systems, and that also needs to recognise variability in human experience and perception.
- The first thing to recognize is that uncertainty on the science side is typically much larger than uncertainty on the economics side. Second, much of the science/engineering work is not directed toward answering the policy questions. When this happens the different parts of the analysis are not lined up and the degree of uncertainty is greatly increased. Third, bringing in economists early is one of the main things that can be done to reduce the level of uncertainty surrounding the overall decision. Fourth, with a sufficient amount of time and money for the research, uncertainty on the social science side can be well understood. Many sources of uncertainty can be made relatively small with large enough samples. Other sources of uncertainty cannot be reduced unless the government is willing to engage in active experimentation (on a smaller scale) but the drivers of it can be well understood.
- Governments have to make decisions on policy issues in the face of substantial uncertainty and should adopt a consistent stance toward how it deals with uncertainty. Often uncertainty and questions about the robustness of valuation techniques are put forward as a rationale for maintaining the status quo. Further, those who oppose a proposed decision will always have an incentive to attack the underlying basis for it, whether on the science or social science side.
- Any effort to monetize changes in environmental amenities picks up a coalition of opponents on both extremes, those who think that the environment is priceless and hence fear that the public will not value it enough and those who like the current implicit price of zero who fear that any monetary value that the public places on resources will undermine their use of it for free.

A number of respondents, both natural and social scientists, raised the issue of variation in scale, space and time (BOX G). A number pointed out that much NRRES data relate to the micro scale, for specific circumstances and collected over specific time periods. These data

are extremely useful, but they may not be entirely suitable at the larger scale in the context of higher level valuations such as catchment scale assessments of flood generation from farm land. Nor may they be suited to considering marginal effects. Some data sets (and modelling capabilities), tend to focus on discrete components of systems, such as nitrate leaching through the soil profile, without joining up to the larger catchment scale of the type needed to support valuation of water quality impacts. In this respect, there was a perceived need to consider how detailed environmental knowledge could be "upscaled" and "translated" to make it more accessible, with suitable and meaningful concepts being provided for those involved in valuation research.

Some suggestions were made about how the information could be provided, for example through detailed case studies. One respondent suggested that use of case study sites was needed to elicit the impact of policy; another suggested that visualisation techniques might help interviewees in valuation experiment.

BOX G: Selected comments on variation and scale in valuation studies

- bridging or up-scaling finely detailed knowledge to more understandable/accessible concepts
- Ecological measures need to be developed that provide suitable endpoints for valuation - i.e., measures that people can understand in terms of personal experience
- There is a need for experimental research but this would require significantly increased funding
- It would be helpful to have a better understanding of extent and survival of historic landscapes and features to help identify priorities for landscape management research.
- Translation from regulation to measurable environmental change is difficult and often simply presumed. Translation from environmental changes that are easily measured to environmental changes that the public cares about is sometimes outside the range of current ecological knowledge.
- Our study considered all of the UK's territorial waters - research is required on specific case studies to determine the impact of policy changes
- the effect of transport schemes on landscape should be assessed once the scheme is matured. Visual evidence for this may be lacking (e.g. Photos of a place before the scheme, immediately after, 5 -10 - 15 etc months / years later)
- We have tried to incorporate images and visualisation within our studies, and this strikes me as being a valid route for further exploration in both theoretical and applied terms.

Social and economic sciences

Some respondents made specific suggestions about what needed to be valued. These included water run off across landscapes, values of aesthetic changes, intrinsic values for biodiversity and heritage, noise, and the impacts associated with climate change. It was argued (BOX H) that we know far too little about how values (in the psychological sense) come about and change. It was argued that the influence of media, lifestyles, peers, own experience, and school curricula on attitudes towards the environment was 'obvious but not well understood'. For some, this called for extending the amount of behavioural and neuroscience research in an attempt to overcome the limitation of partial analyses that only investigate small segments of the 'real world'

BOX H: Selected comment on understanding environmental values

- Our knowledge might be generally sufficient but I believe that we set the wrong priorities - the emphasis on economic valuation is, in my view, misled and won't help us if we want to UNDERSTAND people's values and behaviour - economic valuation has, in my opinion, only a strategic function, namely to make policymakers more aware of environmental issues and the externalities of their decisions.

Finally, there was a call for ways of improving the robustness of valuation estimates by doing two things: first by improving the way existing methods are used, as referred to above, and second by extending the methods used, especially with regards to enhancing participant knowledge and understanding of the topic of valuation (BOX I). Suggestions were made regarding greater use of deliberative methods such as interactive workshops, 'learning schools', citizens juries, and critically enhanced methods of visualisation to enable participants to construct understandings of hypothetical choices that otherwise remain abstract and difficult to appreciate. Respondents noted that these methods require more time, but the results are likely to be more reliable.

BOX I: Selected comments on improvements to valuation methods

- Further refinement of existing valuation methods is needed, particularly benefit transfer.
- Need to improve the scope of elicited preferences and reduce the psychological demands and biases.
- Alternatives to the traditional benefit-cost framework would be useful but these must provide defensible measures based on people's preferences.
- The relationships between and interaction of social and economic drivers and the natural environment, in both directions,
- Experts need to live with the fact that individuals hold different values
- We need better ways of incorporating values into decisions where there are multiple objectives
- Our valuations are moving away from things that people are familiar with. It is apparent that answers become very variable when people don't know much about what you are asking them.
- There is much scope to combine revealed preference with stated preference methods in a 'learning environment', linking actual behaviour with likely behaviour

A significant problem flagged was in terms of defining whether what is measured by environmental scientists is a good proxy for the values sought (BOX K). A further issue related to how well expert understanding of how the environment works could be translated for use by social scientists. This requires making a link between indicators and processes relevant for the analysis of environmental change, such as chemical properties of water, and the value of water to different users of water, such as local residents, riverside walkers or anglers.

BOX K: Selected comments on improvements to valuation methods

- There is a problem with whether what is measured is a good proxy for the values sought.
- State of scientific knowledge can always be improved, but existing methods have usefulness as long as their limitations are recognised.
- Need more synthesis, integration, and modelling.

- There are well founded theories and modelling approaches. Key concerns surround strategic biasing of response and presentation of environmental factors to respondents in ways that are meaningful.
- To increase the policy use of the valuation estimates we need to make sure that physical impacts (as described by natural scientists) are "translated" to something which is understandable to the general public in Contingent Valuation Studies and Choice Experiments, and at the same time is scientifically correct. This demands more co-operation and openness between natural scientists and economists, and those studies that manage to do this also seem to play a larger role in decision-making.

Integration of social and environmental sciences

Opinion was divided as to whether integration of sciences was problematic in valuation research. Approximately half of the respondent stated that integration could be achieved, even if it was problematic. Those who said it was not problematic suggested that this was so, because “it is just a matter of getting the social science modellers and the hard scientists together” and that “when this happens each contributes to the understanding and methods of the other”. These were barriers that could be overcome with “open-mindedness” and “regular communication and planning” and it was stated that interdisciplinary research “can be done if researchers from different disciplines take a positive approach to multi-disciplinary work”. On the whole, although it may have been difficult, “more and more biologists are willing to work with economists, and economists have made quite an effort to learn and be patient with biologists”. It was suggested that the development of ecological economics, with biologist trained as economists, had done much to help this process.

However, strong views were also aired on the difficulty of achieving the integration that is needed for valuation research. The links and relationships between the natural and social sciences were not always well understood or quantified. It could be that there was “lack of interest in what the 'other side' is up to” and that the “rewards” and “incentives for true multi-disciplinary work are not good”. Others stated that there was complexity in the science and practical considerations such as funding, which made integration difficult. Some economists were critical of the ability and willingness of natural scientists “to join things up”, sometimes preferring to work in very specialist areas, without “engaging with the bigger picture”. To be fair, this perception arises because natural sciences designed to provide detailed understandings are being required to support the appraisal of policy options with different requirement in terms of temporal and spatial scales. Thus the tensions arise because of mismatching of purposes. BOX L contains the selected views of respondents regarding the challenges of integration of scientific perspectives.

BOX L: Selected comments on integrating the sciences

- Economists have pretty good methods but do not understand enough about the environmental services. Environmental scientists need to recognise the economic theory and either cease to impose absolute values on environmental resources or demonstrate how economic methods could be improved. At present there is surprising arrogance amongst environmental scientists who seem willing to dismiss arguments/methods that have had a great deal of mind power devoted to them by social scientists.
- Interdisciplinary research is made difficult by the structure of disciplines within Universities and the ways in which academic careers progress.

- It can be difficult to bring together approaches which are quantitative and qualitative; and those which seek objectivity and those which seek to capture a rich set of experiences of place.
- The relationships between the natural environment and social and economic development is not well understood and has not been quantified.
- Need to use common framework and terminology
- Economists, social scientists and environmental scientists each have their cherished preconditions for analysis and discussion. When dialogue takes place, it is often token. When researchers try to take a perspective which integrates approaches and perceptions, they are either abused for impurity from all directions or ignored as trivial or subversive. Yes, I know, I've spent my working life there.
- Economic models seem to be predicated on the notion that things will go up before they come down.
- I always thought economic models were the problem, until I began to scrutinise models used by natural and physical scientists.
- The main problem with valuing ecosystem service benefits is that the science is not well developed. If we do not understand the flow of ecosystem service benefits then they cannot be valued.
- Yes, it is typically problematic. Much of the problem lies on the science side, particularly when dealing with ecosystems, as it is at a much more primitive level of understanding than the social science/economics side. At the other end of the spectrum, some of the engineering/physical science is at a more developed level than the social science/economics side. Integration is an issue but thinking in terms of integration is often the source of the problem. Integration is something that is typically done at the end to bring the different strands of research together. The lack of early coordination and the lack of a clear definition of and focus on the main policy questions is usually the underlying source of problems in later integration of results.

Respondents suggested that several things were important for closer integration between the social and environmental sciences (BOX M). Practical considerations included the need for long-term funding of research, with proper appraisal of the requirements for integration being specified early on in projects. Regular interaction was also seen as important, for example through conferences, seminars, other fora, through interdisciplinary research programmes such as the Joint UK Research Council Funded Rural Economy and Land Use Programme (RELU), and also informally. The career progression of scientists involved in interdisciplinary research needs to be fostered. University departments and other research organisations need to be structured so as to enable effective capacity in interdisciplinary research to develop. Some of these suggestions have implications for the way that integration can be achieved in practice. Recognition and reward were important aspects of encouraging the kind of integration required for NRES valuation. These points were further elaborated during personal interviews.

BOX M: Selected comments on achieving integration of sciences in practice

- To improve integration requires LONG-TERM (5-6 YEARS) funding to develop a working relationship, then collect the data, and analyze results.
- By funders ensuring that the different skills are represented in research. Conferences would do well to have sessions on how each might learn from the other
- Careful design of research programmes. Integration to be set as a criterion by research funders

- Encourage interdisciplinary discussion (e.g. create a forum for regular discussion) and interdisciplinary research projects.
- Enhancing the credit given to humility and openness to discussion.
- Funding of integrated projects, where social and environmental science is integrated and not just done in isolation would help. Multidisciplinary workshops can help too.
- Greater recognition of interdisciplinary research and of applied research.
- I think the main challenge is to overcome the dominance of economic valuation techniques - so I see the problem in the collaboration between economic and other social sciences rather than between socio-economics and ecology
- Lots of opportunities to speak to each other; to go out in the field together and discuss different ways of understanding and valuing nature. To work towards open-mindedness about different approaches.
- More research funding for econometric analysis of relationships (including Bayesian spatial analysis) between the quality of the natural environment and economic development. This area is not yet sufficiently developed to allow for applied research, so more research councils funding needs to be made available.
- Programme-based approach to research design that incorporates the necessary disciplines
- There have been few previous studies, so interdisciplinary working should be fostered, possibly through workshops or an initiative such as the EU's Economics of Biodiversity Loss project
- We have successfully used qualitative social science techniques and methods to elicit expert/scientific information

Primary and secondary data for valuation research

A wide variety of primary and secondary data was reported by the respondents as being used in their valuation research.

Primary data

These include data collected on specific sites with respect to environmental conditions and processes, such as habitat surveys, soil and water qualities, or processes such as soil erosion and surface and ground water flows, air quality, noise levels, and land use and farming practices. These were collected through site monitoring some specifically as part of projects, and some as part of on-going monitoring regimes. It was noted that data are expensive to collect and, other than general monitoring, data collection is often tailored to a particular study such that its application elsewhere could be limited. The point was made that data collected for generic purposes may not fit the purpose of valuation, especially relating to new policy areas. However, some respondents thought that much more could be made of existing data sets, especially by ‘joining them up more’ and also by re-orienting some of the on-going monitoring regimes to suit new purposes. The collection of water quality data was a case in point, as noted by the NAO in a recent review of the Environment Agency’s water monitoring programme.

Regarding social science data, it was now common to undertake CV type surveys as part of large development projects, and these had become a regular topic in undergraduate studies and project work. Primary data are collected through interviews, panels, focus groups, use of expert knowledge, increasingly using web-based survey methods, and linked to GIS methods. Primary data of this kind were usually suited to specific purposes, although specific attempts might be made to make the data and interpretation suitable for “benefit transfer”. There was a feeling expressed by some that numbers without context lack meaning.

BOX N: Selected comments on data collection for valuation

- Valuation data almost invariably needs to be situation specific. The more valuation data we have the better, but it is expensive to collect so there is always going to be a trade off between rigour and what is practical.
- Some data are available, but are limited by the fact that (i) they may be collected infrequently; and (ii) the list of variables/indicators for which data are collected are determined by other needs, usually government reporting requirements, and not specifically for the purposes of econometric evaluation.
- Suitable to some extent but limited unless attempts are made to go beyond quantitative data
- These data are suitable, but are only available in a limited number of cases
- while useable there is some compromise in using the data: between precise/complex data and useable (in the CE) more generalised concepts
- primary data are specific to particular research studies, but benefit transfer techniques offer some scope to make data more widely useful, (and this should be considered when data are being collected)
- Situation specific primary data would be ideal, but is not always available or practical to collect. BT values are OK if they are used wisely and problems highlighted.

It was suggested that primary data could be improved by a variety of means, for example through better "understanding and reflection". Data appeared to be missing for particular segments of the population. It was argued that people's views on intangibles such as landscape and sense of place were treated as "idiosyncratic and hopelessly subjective". It was suggested that more data on where people do have real choices would be useful. Further research on stated choice research was proposed for non-use values, especially existence values.

One repeated concern about primary data was the limited information on how people actually use the environment in Britain, including spatial and demographic variation in use (BOX O). Data was available on selected sites, such as canals and forests, but beyond this information on actual use of the landscape and its environmental attributes was limited, compared, it was suggested to the USA case. This point was also made with respect to a call for revealed preference studies which monitor actual rather than expressed behaviour. It was noted that data on non-use values are limited and challenging to obtain.

BOX O: Selected comments on primary data for valuation

- More data are needed on actual behaviour where people do have real choices - so discrete choice Revealed Preference data on where people live and why and where they travel to. These are disaggregate version of the travel cost and hedonic methods
- Importance of taking account of individual and community sense of place and aesthetic valuing. Avoid assumption that such views are idiosyncratic of hopelessly subjective. Attempt to understand value inter-subjectively
- There tends to be a lack of data for specific segments of the population
- Non-use values, especially, existence values, and values from widespread but small recreational values derived from biodiversity. - e.g. every time a walker hears a skylark singing, what is that worth? Maybe 1p or 0.01p, but then there are millions of walkers

Secondary data

Secondary data includes published survey (house prices, farm business data) and census data or data on published in previous valuation papers, local authority data, visitor numbers and data from government agencies such as Defra. The use of primary data collected by other projects through interviews and focus groups and transferred to new or extended applications was also important. Many physical data were also mentioned, such as data on carbon emissions, fishing catch, biomass production, meteorological data, land cover, soil maps, and air pollution data, and also the use of air-photos, texts on aesthetic appreciation of nature in landscape history, garden history, philosophy, conservation literature, literature in environmental ethics, verbal descriptions, photos, films showing noise levels and traffic movement.

It was felt that there was considerable scope for using secondary data in valuation research, especially drawing on natural science data sets to identify baseline and change scenarios, and relevant scientific indicators that could then be 'transposed' into social science applications. In the view of one respondent, it was "just a question of understanding what the available data mean, and how to interpret them". However, there were limitations, for example, the most obvious being that the data were not collected for the research in question. In the case of landscapes, one respondent said that the creation of meaningful datasets was hampered by missing data, such as the stocks of linear features and by lack of consistency in how those data were collected at different scales in different locations. Water resources and quality data may be in a form or location suited to 'user' valuation. By comparison soils data was available in a form that indicated suitability for particular uses. Secondary data were also in some cases considered to be difficult and increasingly expensive to acquire. The availability and quality of data sets were perceived to vary between applications in specific areas of valuation research. But many respondents thought that some data sets were underutilised partly because they had not been integrated and/or offered in accessible ways, such as in GIS format. BOX P contains selected comments on the use of secondary data.

BOX P: Selected comments on use of secondary data

- We have found major gaps in available data for biodiversity. The only data we could obtain at a fine enough resolution (LSOAs or similar scale grids) with coverage over the whole of England was on birds, deer and badgers.
- Data for individual properties and the households within them are essential and these are difficult to get. Quality GIS data is expensive and OS data increasingly commercialised for academic use.
- Depends on the problem being addressed - data on values of recreational fishing are readily available and excellent; other areas are not as good
- In this case, the data were readily available and generally considered suitable. There were problems with the soil model used and its parameterisation for a specific area in Scotland: how suitable was this for generating values relevant to the whole of the UK?
- Often not accurately recorded, and may indicate car movements and visits, not visitors.
- Quite patchy and inconsistent formats and difficult access. Not often electronically available or easy to process. Conservation and estate maintenance decisions are poorly recorded
- Rely upon someone else's definitions of variables and spotty collection

- Some data are available, but are limited by the fact that (i) they may be collected infrequently; and (ii) the list of variables/indicators for which data are collected are determined by other needs, usually government reporting requirements, and not specifically for the purposes of econometric evaluation.
- The costs, profits, jobs for the fisheries are relatively well known for the commercial fisheries, but not for recreational and artisinal fisheries
- There is much debate about how to reduce landscape to discrete datasets that have some meaning. There is a lack of national data about the total stock of specific features – such as different types of boundary. There is variability in local approaches to landscape character assessment (although there is a standard national method, usually applied at the scale of individual local authorities and protected landscapes). Natural England is currently undertaking a review of landscape evidence. In the course of this review it aims to look in more detail about the kind of data that is needed, at what scale, and also at the available methods.

From the comments above, it was evident that data needed to be made more accessible, that they could be improved by ensuring better time-series data and spatial coverage of the data and ensuring that they do not conflict at different scales (BOX Q).

BOX Q: Selected comments on improving data accessibility

- Much data on the public good are now held in private domains
- Readily available individual property and especially household income data
- Top down planning of policy means national and local data do not agree
- Data are often limited, e.g. time-series are too short or spatial data are limited
- More detailed data on tree age and structure in maps that indicate 'forest'; better crop maps
- More disaggregate data on actual choices from amongst the set of house (or other alternatives) available
- There is need for data on the role of biodiversity in motivating recreational activity

Valuation output data and results

Respondents reported that they produced the results of valuation in the form of project reports, papers, models, maps, and databases. On the questions of whether the outputs were suitable for use in decision making, most of those who replied answered in the affirmative.

There were four main camps reflecting a continuum from practitioner to (pure) research applications. First, the use of valuation to support major investment decisions, mainly the preserve of consultants; second, the use of valuation for policy design and choice (that is policy driven), mainly involving consultants and research contractors; third, valuation as part of longer term strategic reviews (policy relevant), mainly involving research institutes and Universities, and; fourth, new developments in valuation methods (usually applied to policy relevant issues) usually undertaken by academics. This continuum is also reflected in differences in audiences, techniques used and the means of communicating outputs.

With respect to the interpretation of valuation outputs, a note of caution was sounded in that "strictly valuations apply only to one time and one place. Moreover they are only directly applicable to the specific purpose for which they were designed and require specialist knowledge to interpret". One respondent felt that their valuation research was too abstract for policy application, but felt it was nevertheless important to progress the concepts behind valuation research. Another mentioned that due consideration should always be given to the

uncertainty in the outputs, using statistical methods or appropriate written cautions. However, in the words of one respondent, if the research was not applicable to policy, they did not undertake it. The respondents who replied suggested that their outputs could be used in a variety of ways including for impact assessment, for allowing policy-makers to consider tradeoffs between different benefits, for example, from spatially mapped trade-off representations. One respondent stated that valuation outputs considered that such data improved "the case for public spending on the environment" for example, in the context of "the transfer of CAP Pillar I funding to Pillar II".

Regarding uncertainty, most respondents stated that they dealt with this through the statistical measures or approaches. These included use of statistical methods to estimate errors associated with the output data, for example using confidence intervals or correlation coefficients. Sensitivity analysis and stochastic modelling approaches for example with Monte Carlo simulations, were also used. One respondent said that uncertainty was considered through weighting matrices based on expert opinion, whilst another stated that scenario analysis was used. The availability of low cost software for risk modelling should, it was argued, promote the explicit treatment of risks and uncertainty in the analysis and presentation of results. In recent years, capability in the modelling and communication of risk and uncertainty has increased considerably. This is an important area for research.

Perceived stakeholders and stakeholder impacts

The range of intended beneficiaries of valuation research was considerable (BOX R). In the words of one respondent, "the world in general, governments, government agencies, private individuals who want to act rightly". More specifically, mention was made of the national, regional and local government departments, regulatory agencies, conservation organisations, NGO's, and the academic community. Such organisations included the EU, Defra, Natural England, JNCC, DfT, CLG, the Scottish Government, Welsh Assembly, The Environment Agency for England and Wales, the Scottish Environmental Protection Agency, and Scottish Water, RSPB, FWAG, and water companies.

Respondents referred to the general use of valuation in environmental impact assessments, economic appraisals of policy and land management options, and consideration of non-market benefits in decision-making. Some specific examples are given in BOX S:

BOX R: Selected comments on use of valuation work

- The DfT recommended noise valuations took account of our work
- Work on aviation abatement options informed climate change negotiations
- Choice experiments on public rights of way informed local authority spend
- Valuation of water in agriculture informed operation of licensing and drought orders
- Press coverage of headline figures
- Provision of evidence base for the Marine Bill
- Use in the hill farming allowance policy design
- Biofuel research has cited and referenced in the US The Energy Independence and Security Act of 2007
- Estimates of the social benefits of reducing eutrophication and acidification of lakes and rivers have been used by the Norwegian Ministry of Environment and Norwegian EPA in their CBAs of measures to reduce eutrophication and remediation (liming) of acidification (and fish kills) in lakes and rivers in Southern Norway. My valuation

estimates of environmentally related health effects have also been used by the Norwegian EPA in their CBAs of measures to reduce air pollution.

- Several studies: including Elwha Dam Removal in Washington's Olympic National Park, Poudre River instream flow study in Fort Collins, Colorado.
- Support for the U.S. Clean Water Act submitted to the U.S. Congress as U.S. Environment Protection Agencies benefit estimate and used to assess a wide range of specific regulations. The work on water reliability has been used to help determine water pricing and investments in conservation. The work on the Exxon Valdez served as the basis for the government's settle for ~ 3 billion dollars (2 billion in restoration expenditures and 1 billion in natural resource damages).

Future priorities

Respondents proposed a wide range of future priorities (BOX S). These cover both social and environmental sciences as well as methodological issues and gaps in data provision.

On data, there was a call for increased monitoring of actual use of NRES, for example in terms of use of the countryside for different purposes by different users. There was also a call for joining up different data sets to suit particular applications.

On methods a number of priorities were identified. These included developing integration between quantitative and qualitative methods, especially joining CBA methods with multi-criteria and qualitative, and narrative-based assessments of values and preferences. More attention was required to enhance the robustness of stated preference methods, especially understanding how and why people make decisions, and how choices vary according to factors not included in choice sets – essentially identifying and explaining variance in valuation. It was recommended that drawing on new developments in neuroscience and psychology will add much to valuation studies. These suggestions were also linked to proposals to make choices 'more realistic', by for example, creating a 'learning and knowledge exchange environment', practical exposure to different environments, and visualisation. It was noted that while this is possible, it is also expensive.

There was a call for more emphasis to be placed on revealed preferences, that is, actual behaviour. It was felt that this was under researched, and for example, more could be done on exploring how people actually make choices on environmental quality and how values are actually derived. This might involve new combinations of hedonic and travel costs methods, from which more realistic estimates of responses to new circumstances might be obtained.

In a general context, it was suggested that the ecosystems concept provides a useful framework for priority setting for valuation. It was important, for example, to identify the critical links between social welfare, defined at the relevant scale, and the state of, and changes in, NRES. Identifying key relationships, and related policy arenas, should guide valuation research. Furthermore, a greater depth of understanding on uncertainty, thresholds and resilience was urgently required and guidance provided on how this should inform valuation.

Respondents also suggested that, "non-trivial collaboration with other disciplines" should be promoted to develop new approaches to valuation, but also in recognition of the need to use valuation data with due care and attention to its limitations. It was critical to develop relevant valuation scenarios. Mention was made of the need to improve the "quantification of policy outcome", showing how valuation led to decisions that made a difference.

A number of respondents referred to the need for best practices guidance on the use of valuation studies for non-academic practitioners involved in project and policy appraisal.

BOX S: Selected comments on priorities for future valuation studies

- Developing a research strategy on climate change impacts for historic parks, gardens and designed landscapes. Developing remote sensing tools for monitoring condition and change in historic parks, gardens and landscapes to inform policy and landscape management conservation. Developing better information base about inter-relationship between wildlife and habitats and historic landscapes to inform conservation management.
- Deliberative decision-making; alternatives to quantitative and CBA approaches.
- Development of Ecosystem Assessment methods, greater uptake of Ecosystems Assessment principles, development of information elicitation methods, wider more robust applications of Ecosystems Assessment.
- Disabusing ourselves of the idea that contingent valuation and choice experiments of themselves will give reliable answers. Seeking non-trivial collaboration with other disciplines. Then we can start on the agenda.
- How land use, land cover, and land management affects ecosystem service production and value.
- I believe we need to try as many methodologies as possible, to get a handle on how to evaluate ecosystem services.
- Improve ability to isolate values for specific types of 'environmental services; improve ability to value where incompletely capitalised into property values
- Improved quantification of policy outcomes and hence valuation scenarios
- Need greater development of valuation methods; encourage interdisciplinary working
- Identify those aspects of the natural environment that are important for economic development and exploration of the issue of quality thresholds for economic
- There needs to be further research into the ecosystems approach to valuation. Further research also needs to explore uncertainty, thresholds, resilience etc. We also need further research into the value of living organisms in developing countries and benefits at local and international scales.
- Validation of valuations against actual behaviour and comparison of techniques. Extending valuation methods to new areas such as air.
- Water quality, climate change impacts, ecosystem services
- What we are doing will answer the information gaps for the effect of transport schemes on landscape. There are many other gaps...for example soil contamination, loss of habitats to other physical structures and also loss of special habitats.

Respondents were confident that valuation research had an important role to play in the future management of NRES, especially regarding the valuation of public goods and the formulation of policy to improve the sustainability of NRES (BOX T). Both natural and social scientists alluded to the contribution that valuation can make to enhancing social welfare through the provision of public goods and avoidance of environmental damages. Valuation was also important, it was argued, for funding and compensation associated with development. Respondents also saw valuation as a means of securing the future of some vulnerable environmental qualities and systems - by demonstrating their value to people. This might include water quality for anglers or bees for vegetable producers. Capturing these values through market mechanisms, through willingness to pay in practice, could help secure

their future. There was a risk however that non near-market attributes are overlooked, unless care is taken to recognise whole system dynamics.

Respondents argued strongly that context was important and the approach to valuation would vary depending on whether there might be more appropriate, perhaps non-economic approaches to eliciting environmental preferences. "For example, a citizen jury might be used to define values for compensation. Or, the precautionary principal might be applied in combination with valuation. Although political debate and discourse were important, this respondent suggested that "the ones with the most money and biggest financial stake (industry) will push hardest and debate loudest, unless there is a well organized NGO or other citizens' group to push back". In this respect, valuation studies could be used to reflect the well-being of resources to society, rather that to more powerful groups.

All respondents, in various ways, expressed the view that if NERC wishes to ensure that its research has policy relevance, it must undertake valuation research that explicitly considers the relationship between environmental change and changes in social welfare. It should, in the view of some, identify those areas of natural sciences (NRES) research that, once combined with valuation studies, will make most difference to welfare outcomes.

BOX T: Selected comments on the future of NRES valuation research

- Extremely important and growing in importance as more public funds are directed to protection and improvement of the natural environment. At present, largely environmental criteria are used in identifying aspects of the natural environment for public funding and this is done in a broad-brush way without regard to the secondary impacts of these choices on social and economic development.
- Undoubtedly, most policy is developed from policy rather than from scientific data, the assessment and evaluation of prior policies and their actual rather than planned impacts are essential.
- Whether one agrees with valuation or not, given the level of interest by decision-making bodies such as Defra, valuation research is moving higher up the agenda and has the potential to play a significant role in future policy and decision-making.
- Yes - the only useful evidence base for much decision making re land use/conflicts
- Yes - we need economic value evidence to compare the environmental costs and benefits of policy and project decisions against their financial / market economic costs and benefits. With improved knowledge and practice, this use will only improve.
- Yes - we need to understand the optimal level of conservation and also to balance conservation with commercial interests, especially the greater exploitation of the marine environment for renewable energy
- Yes, I hope it helps policy-makers cogniscent of all the monetary ramifications of different land uses. I want my research to help policy makers realize that land use creates a vector of values that, once put in monetary metric terms, are comparable.
- Yes, if only in establishing when various non-market values for biodiversity are positive and significant and/or are relatively greater than values from competing resource uses
- Yes, if this research is broad and rich; and not overly reductive. Important to capture the complexity of landscape itself and our experiences of it
- Yes, through on-going research that addresses policy choices. Incorporating other social techniques (qualitative approaches) and scientific understanding will make such work more robust and respected

- Yes, valuation of environmental features/issues increasingly seen as important by Defra, EA and others. Becoming an integral part of the policy making process.
- Yes, without the research policy makers will have to make decisions in the dark. It would be useful if the policy makers and scientists could get together to decide how best to proceed and what is needed, so that scientists can answer the questions of how to evaluate ecosystem services.
- Yes. Assessing the benefits of living organisms in economic and social terms will help policy makers design better policies.
- Yes. The costs and benefits of different policies and investments need to be evaluated and valuations are essential for this
- Yes. Through dialogue.

Appendix B : The questionnaire structure, questions, and options

Table B. 1. Questions and options used for the international survey of valuation researchers

1.1.1	**What is the broad topic area for your research:** **Options**: Air - land - water - living organisms - energy
1.1.2	**Which organisations have funded your valuation research? –**
1.1.3	**Please list the ecosystem services you have valued:** **Options:** Aesthetic value - Air quality regulation - Aquaculture - Biochemicals - Capture fisheries - Climate regulation - Crops - Disease regulation - Energy provision - Erosion regulation - Fiber crops - Fresh water provision - Genetic resources - Habitation - Livestock - Mining - Natural hazard regulation - Natural medicines - Ornamental resources - Pest regulation - Pharmaceuticals - Pollination - Recreation - Religious value - Spiritual value - Timber - Tourism - Tourism - Transportation - Waste disposal - Waste treatmement - Water purification - Water regulation - Wild foods - Wood fuel – -
1.1.4	**What are the main drivers of environmental concern for these ecosystem services?** **Options:** Agricultural development - Air pollution - Bio-accumulation of toxic substances - Biodiversity loss - Climate change - Congestion - Crowding - Habitat conversion - Infrastructure development - Invasive species - Loss of - Loss of agricultural landscapes - Loss of heritage - Loss of natural landscapes - Loss of rare birds - Loss of rare fish - Loss of rare mammals - Micro-organisms - Mining - Noise - Non-toxic substance - Over exploitation of forests - Persistent substance - Predominantly anthropogenic substance - Resource extraction - Soil degradation and erosion - Solid waste - Toxic substance - Water abstraction - Water pollution
1.2.1	**What is the main category of the valuation methods you have used?** **Options:** Economic - Social - Environmental
1.2.2	**What specific valuation methods have you used in your valuation research?** **Options:** Actual expenditure/market price of output - Averting behaviour (preventative, defensive, etc.) - Change in productivity - Choice experiments - Citizens juries - Combined revealed and stated preference - Conjoint analysis - Contingent valuation - Count data models - Defensive expenditure - Delphi method - Demand analysis - Does response - Experimental cash market value - Expert panels - Gaming - Hedonic pricing - Scoring methods - Weighting methods - Ranking methods - Replacement costs - Travel cost method - 3-D Computer Visualisation
1.2.3	**How suitable have you found these methods?** **Options:** Highly suitable - Suitable - Neither suitable or unsuitable - Unsuitable - Highly unsuitable - I don't know - Not applicable
1.2.4	**In the boxes provided, please explain your answers to Question 1.2.3….**
1.2.5	**What type of decision support approaches have you used in your valuation research?** **Options:** Bayesian simulation - Collective choice methods - Cost effectiveness - Cost-benefit - Econometric (regression based) methods - Environmental Accounting - Life Cycle Analysis - Multi-criteria - Neural networks - Programming and simulation - Risk-based assessments
1.2.6	**How suitable have you found these decision support approaches for valuation research?** **Options:** Highly suitable - Suitable - Neither suitable or unsuitable - Unsuitable - Highly unsuitable - I don't know - Not applicable
1.2.7	**In the box, please explain your answer to Question 1.2.5….**
1.3.1	**In your opinion, does current scientific knowledge and understanding in environmental and social sciences provide a suitable basis for valuation research?** **Options:** Highly suitable - Suitable - Neither suitable or unsuitable - Unsuitable - Highly unsuitable - I don't know - Not applicable

1.3.2.	**In the box, please explain your answer to Question 1.3.1….**
1.3.3	**In your opinion, where are the gaps in scientific knowledge and understanding and how could these be improved?**
1.3.4	**In your opinion, is the challenge of integrating environmental and socio-economic sciences problematic in valuation research?** **Options:** Very problematic - Problematic - Only slightly problematic - Not problematic at all
1.3.5	**In the box, please explain your answer to question 1.3.4….**
1.3.6	**In your opinion, how could integration of environmental and social sciences for valuation be improved?**
1.3.7	**Describe the data you have used in valuation research**
1.3.8	**In your opinion, are the primary and secondary data that are available, suitable for valuation research?** **Options:** Highly suitable - Suitable - Neither suitable or unsuitable - Unsuitable - Highly unsuitable - I don't know - Not applicable
1.3.9	**In the boxes, please explain your answers to question 1.3.8….**
1.3.10	**In your opinion, where are the gaps in data provision for valuation research?**
1.3.11	**Please describe the key outputs you have generated in your valuation research**
1.3.12	**Explain how uncertainty has been dealt with in your research?**
1.3.13	**Are the outputs you describe suitable for decision-making?** **Options:** Highly suitable - Suitable - Neither suitable or unsuitable - Unsuitable - Highly unsuitable - I don't know - Not applicable
1.3.14	**In the box, please explain your answer to question 1.3.13….**
1.4.1	**Who were/are the intended users of your valuation research?**
1.4.2	**How has your valuation research contributed to improvements in natural resources management?**
1.4.3	**Have there been specific applications of your valuation research?**
1.4.4	**Stakeholder Name** **Level of 'INTEREST' in valuation** **Options:** Extremely interested - Very interested - Interested - Moderately interested - Slightly interested - Not interested
	Level of 'INFLUENCE' in valuation **Options:** Extremely influential - Very influential - Influential - Moderately influential - Slightly influential - Not influential
	Do you have formal or informal links with this stakeholder? **Options:** Formal links - Informal links - Both formal and informal links - No links
1.5.1	**What do you consider to be the priorities for future valuation research?**
1.5.2	**Do you think valuation research has an important role to play in future policy and decision-making? If 'Yes', describe how you see this happening…**
1.5.3	**Please provide us with any other feedback you would like to make…**

Appendix C : Results of CAB search For NRES Valuation Literature

Table C. 1. Number of times that research organisations and authors were counted in the Inventory references

Research organisation	
Name	***No***
Colorado State University	54
Swedish University of Agricultural Sciences	40
University College	38
USDA Forest Service	36
University of California	32
University of East Anglia	31
Newcastle upon Tyne	31
University of Newcastle	30
University of Newcastle upon Tyne	25
University of Georgia	25
Iowa State University	24
University of Alberta	23
University of Wales	21
Michigan State University	21
University College London	20
Ohio State University	20
USDA Forest Service	20
University of Reading	19
Texas A&M University	19
Agricultural University of Norway	19
University of Maryland	18
Purdue University	18
North Carolina State University	17
Lincoln University	17
World Bank	16
North Dakota State University	16
University of Cambridge	15
Cornell University	15
Vrije Universiteit	14
University of Stirling	14
University of Queensland	14
University of Helsinki	14
University of Florida	14
INRA	14
University of Wisconsin	13
The Ohio State University	13
East Carolina University	13
Department of Town and Country Planning	13
University of Maine	12
University of British Columbia	12
Royal Veterinary and Agricultural University	12
Australian National University	12
University of Tennessee	11
University of Nevada	11
University of Minnesota	11
Georg-August-Universitat Gottingen	11
Canadian Forest Service	11
Wageningen University	10
University of York	10
Macaulay Land Use Research Institute	10
Kyoto University	10

Table C. 2. Geographical location, language, year of publication and type of publication

Geographical location		Language of reference		Year of publication		Type of publication	
Location	***No.***	***Langauge***	***No.***	***Year***	***No.***	***Type of reference***	***No.***
USA	713	English.	2783	2008	223	Journal article	2541
UK	204	German.	131	2007	311	Book chapter	268
Germany	118	Spanish.	82	2006	279	Miscellaneous.	146
Spain	102	Chinese.	74	2005	279	Conf. paper	123
India	101	Italian.	57	2004	280	Bulletin.	149
Canada	88	French.	44	2003	235	Book.	92
Australia	87	Japanese.	43	2002	227	Journal issue.	31
Italy	85	Russian.	36	2001	183	Conf. proceedings	17
China	83	Polish.	28	2000	149		
Sweden	75	Portuguese.	17	1999	188		
Japan	69	Czech.	13	1998	126		
Europe	54	Hungarian.	12	1997	136		
France	51	Slovakian.	9	1996	125		
Finland	49	Croatian.	5	1995	126		
Dev. Countries	48	Dutch.	5	1994	139		
Norway	41	Slovenian.	4	1993	81		
New Zealand	39	Norwegian.	4	1992	46		
South Africa	36	Finnish.	4	1991	47		
Netherlands	35	Danish.	4	1990	22		
Brazil	33	Lithuanian.	4	1989	27		
Taiwan	28	Korean.	4	1988	16		
Greece	27	Turkish.	4	1987	14		
Russia	26	Swedish.	2	1986	18		
Niger	26	English	2	1985	18		
German Fed. Rep.	26	Greek.	2	1984	13		
Czech Republic	25	Persian.	2	1983	15		
Costa Rica	25	Indonesian.	2	1982	8		
Nigeria	24	Ukrainian.	1	1981	11		
European Union	24	Afrikaans.	1	1980	2		
Denmark	24			1979	10		
Poland	22			1978	8		
Korea Republic	22			1977	5		
Austria	22			1976	2		
Indonesia	21			1975	2		
Philippines	18			1974	2		
Mexico	18			1973	3		
Turkey	17			1972	1		
Nepal	17						
Malaysia	17						
Hungary	17						
USSR	16						
Switzerland	16						
Sri Lanka	16						
Kenya	16						
Thailand	15						
Mediterranean	13						
Israel	13						
Africa	13						
Zimbabwe	12						
Tanzania	12						
Portugal	12						
Slovakia	11						
Madagascar	11						
Croatia	11						
Vietnam	10						
Slovenia	10						
Ghana	10						

Table C. 3. Count of environmental indicator keywords with in the Inventory references

	Air	Climate	Global warming	Atmosph	Carbon	Land	Wetland	Woodland	Soil	Peat	Landscape	Beach	Coast	Water	Marine	Sea
Air	69															
Climate	4	73														
Global warming	1	8	13													
Atmosph	5	3	2	20												
Carbon	7	13	3	8	81											
Land	14	34	3	2	35	819										
Wetland	2	7	1		2	42	134									
Woodland	1				6	35	5	59								
Soil	11	17	1	5	20	72	10	3	135							
Peat						5	1			6						
Landscape	5	5		1	10	220	6	15	15		220					
Beach	1	2				4		1	1		3	29				
Coast	2	5		1	1	17	10	1	4		4	14	86			
Water	20	24	3	7	30	122	45	5	63		28	13	31	560		
Marine	1	2				10	3		2			4	12	22	50	
Sea	2	8	2	2	3	19	6		6		3	10	19	38	23	135
Biodiversity	9	14	1	5	29	85	16	11	23		30	1	6	64	7	13
Animal	1			1	2	17	4		3		5		2	7	2	5
Fish	4	3	2	1	3	19	16	1	5		6	3	26	57	22	32
Plant	9	13		2	16	85	10	10	20		26	1	13	38	5	14
fauna	1	1			1	8	2		3		2			4		1
flora	1				1	8	2		3		3			3	1	1
fung		1			2	8			2		4			2		
Forest	24	26	3	10	67	350	22	49	51	5	88	2	17	107	5	30
Micro	2	2		1	5	9	1		5		2		1	11		1
Agricultur	7	17	5	1	16	301	19	17	48	4	82	1	6	99	1	17
Crop	2	11	1	1	10	65	2	4	25		5		3	37		8
Livestock	1	1		2	2	24	6	2	5		5	1		10		4
Food	1				2	18	2	2	3		9	1	3	14	1	13
Human	6	7	1	1	7	36	6	3	12		8	1	5	22	3	11
Recreation	8	9		3	23	145	23	20	20		57	13	28	143	21	29
Touris	8	6		2	9	58	8	4	9		35	11	23	48	23	25
Fishing	3	2	1	1	1	7	5		2		2		10	25	8	8
Hunt	3	1		1	3	23	2	1	5		6		1	10	2	6
Amenity	1	5			5	66	4	11	7		33	4	5	25	5	6
Aesthetic	1	2				31		3	5		26	1	4	10	2	2
Conservation	11	18	2	6	34	240	53	22	51	1	98	5	20	111	18	25
Ecological	6	9	2	4	15	78	30	4	21		25		13	59	5	13
Energy	5	6	2		2	12	3	1	6		3		1	7	1	3
Power	5	2	1		1	17	2		2		6	1		16	3	2
Wind	1	2		2	3	3	2	1	4				1	5		
Biofuel						1										
Renewable		2	1			2								3	1	2
Pollut	45	14	3	9	12	39	12	1	29		9	5	10	94	5	14
Mining	1					4	1							2	1	1
Mine						9		1	5				1	6	1	2
Geol		1			1	2								1		1
Ecosystem	5	14	3	1	14	80	42	6	25		20	1	14	87	13	20
Ecosystem service	3	4	2		6	31	13	2	9		5		3	34	3	5
Environment	42	36	7	13	48	326	69	26	55	2	122	14	42	261	33	59
Natural resource	12	10	4		7	74	22	6	18	1	20	6	12	61	12	14

Table C. 4. Count of environmental indicator keywords with in the Inventory references

	Biodiversity	Animal	Fish	Plant	fauna	flora	fung	Forest	Micro	Agricultur	Crop	Livestock	Food	Human	Recreation	Touris	Fishing	Hunt
Air																		
Climate																		
Global warming																		
Atmosph																		
Carbon																		
Land																		
Wetland																		
Woodland																		
Soil																		
Peat																		
Landscape																		
Beach																		
Coast																		
Water																		
Marine																		
Sea																		
Biodiversity	250																	
Animal	10	130																
Fish	11	5	174															
Plant	45	20	18	295														
fauna	5	1		3	14													
flora	3	1		2	8	12												
fung	2	1		10	1	1	18											
Forest	128	20	20	169	9	7	12	997										
Micro	2	1	1	8	1	2	1	16	37									
Agricultur	38	25	15	34	3	4		99	8	578								
Crop	21	14	2	45	1	1	3	45	3	74	174							
Livestock	10	32	5	3				11		26	16	83						
Food	10	29	17	37	1	2	2	18	6	68	26	13	343					
Human	28	15	6	11	1			36	1	20	9	8	15	150				
Recreation	35	7	74	19	3	1	4	233	1	55	11	3	11	13	599			
Touris	26	4	17	16	4	4	1	74	3	22	2	2	2	4	102	253		
Fishing	4	3	73	2				6		4			3	1	41	7	73	
Hunt	7	13	11	5	1		1	30	2	10		1	2	3	41	5	10	79
Amenity	13		8	16			2	119		28	4	3	1	6	142	26	4	4
Aesthetic	11	3	1	11				32	1	11	1		4	5	20	8		3
Conservation	156	33	32	71	10	9	2	241	10	123	29	17	19	30	99	73	10	14
Ecological	44	9	15	29	1	1		94	3	40	12	5	17	25	21	23	5	3
Energy	2	4	3	12			1	13	2	9	7		2	5	3	2	2	2
Power	2		4	10				15	1	16	2	2	1		11	4	3	2
Wind	3	1	1	3				9	3	1	1	2	1		6	3	1	1
Biofuel		1								2			1					
Renewable	2	1		4				6	1	3	2			3		1		
Pollut	16	2	25	17	1	1		33	5	40	8	7	3	18	33	13	13	3
Mining	1			1				3		2	2			2	4			
Mine	1		1	1				1		4	3	1		1	2			
Geol				1				3		1	1				1			
Ecosystem	68	10	29	32	3	1		99	4	37	10	5	8	38	34	17	4	4
Ecosystem service	18	2	11	13				27	2	13	3	1	3	15	12	2	1	2
Environment	142	39	65	98	10	7	5	364	21	213	44	22	74	73	195	111	21	22
Natural resource	40	13	15	22	3	3	1	89	5	53	10	7	12	29	62	32	7	5

Table C. 5 Count of environmental indicator keywords with in the Inventory references

	Hunt	Amenity	Aesthetic	Conservation	Ecological	Energy	Power	Wind	Biofuel	Renewable	Pollut	Mining	Mine	Geol	Ecosystem	Ecosystem service	Environment	Natural resource
Air																		
Climate																		
Global warming																		
Atmosph																		
Carbon																		
Land																		
Wetland																		
Woodland																		
Soil																		
Peat																		
Landscape																		
Beach																		
Coast																		
Water																		
Marine																		
Sea																		
Biodiversity																		
Animal																		
Fish																		
Plant																		
fauna																		
flora																		
fung																		
Forest																		
Micro																		
Agricultur																		
Crop																		
Livestock																		
Food																		
Human																		
Recreation																		
Touris																		
Fishing																		
Hunt	79																	
Amenity	4	201																
Aesthetic	3	12	56															
Conservation	14	31	17	603														
Ecological	3	4	10	83	242													
Energy	2	1	1	7	7	47												
Power	2	1	2	9	7	11	65											
Wind	1	0	1	4	3	2	1	17										
Biofuel	0	0	0	0	0	2	1	0	3									
Renewable	0	1	1	1	1	10	5	1	1	20								
Pollut	3	10	2	34	17	11	5	1	0	3	189							
Mining	0	1	0	2	4	0	0	0	0	1	2	13						
Mine	0	1	0	2	3	2	0	1	0	0	0	2	18					
Geol	0	0	0	0	0	0	0	0	0	0	0	0	0	4				
Ecosystem	4	5	7	93	72	6	4	2	0	3	20	1	3	0	254			
Ecosystem service	2	2	3	29	26	1	3	1	0	0	5	0	1	0	82	82		
Environment	22	65	32	310	136	24	28	3	2	8	133	7	6	2	151	49	1178	
Natural resource	5	20	5	90	51	8	4	1	0	11	43	5	2	0	63	21	215	334

Table C. 6. Environmental and economic valuation keyword search within references

Environmental characteristic	Total	Valuation	Contingent valuation	Willingness to pay	Non-market benefits	hedonic	travel cost	stated preference	revealed preference	benefit* transfer	production function	market price
Air	69	57	34	28	12	7	6	4	1	4	1	1
Climate	73	63	23	20	17	4	4	1		5	1	2
Global warming	13	12	2	3	1	2	1			1	1	
Atmosph	20	19	8	8	5	1	1	1				
Carbon	81	73	26	18	32	3	3	4		5	1	3
Land	819	748	273	234	148	55	35	16	5	20	17	25
Wetland	134	128	62	48	22	5	9	3	1	5	9	4
Woodland	59	54	28	20	27	3	2			1		3
Soil	135	123	36	29	27	8	3	5	1	6	2	9
Peat	6	6	5		2					2		1
Landscape	220	199	115	91	61	14	17	8		5		4
Beach	29	25	16	17	4	1	6	2	2			
Coast	86	73	38	47	17	4	7	4	5	5	2	4
Water	560	483	258	272	107	27	41	24	13	29	7	15
Marine	50	46	25	26	14	1	7	4	4	2	1	2
Sea	135	109	52	75	21	7	15	9	4	6	1	7
Biodiversity	250	228	100	85	73	5	10	7		8	2	3
Animal	130	98	53	69	14	8	3		2		2	5
Fish	174	143	74	92	27	6	24	8	5	6	4	6
Plant	295	240	62	95	37	9			1	6	3	8
fauna	14	12	5	5	2							
flora	12	10	6	4	1							1
fung	18	14	4	6	1							
Forest	997	886	339	268	282	45	51	13	5	23	18	36
Micro	37	27	12	18	7	1	2		1		1	1
Agricultur	578	487	172	217	92	29	13	13		18	11	22
Crop	174	128	40	74	19	10		1			3	11
Livestock	83	68	30	33	9	7	1	2	1		1	
Food	343	136	51	276	11	8	2	9	4			9
Human	150	118	46	70	30	4	3	6	2	3	3	3
Recreation	599	536	306	249	159	33	140	20	20	21	5	13
Touris	253	199	119	138	48	9	36	8	3	7	1	2
Fishing	73	63	29	34	7	5	15	4	3	4	3	3
Hunt	79	73	46	26	18	4	13	1	3		1	2
Amenity	201	185	98	82	61	24	32	8	9	7		2
Aesthetic	56	46	24	21	21	7	4	2		1		3
Conservation	603	530	296	255	141	17	33	13	5	18	5	12
Ecological	242	221	79	64	58	2	10	3	1	7	7	8
Energy	47	33	9	21	3		1					1
Power	65	49	19	26	11	2	4	1		2	2	3
Wind	17	15	5	3	3							1
Biofuel	3			3								
Renewable	20	14	2	8	4						1	
Pollut	189	165	89	84	31	15	11	10	3	9	3	5
Mining	13	13	6	6	2			1				
Mine	18	18	4	6	2	1	1	1	1			1
Geol	4	4	1				1			1		
Ecosystem	254	239	78	52	76	6	12	6	2	8	5	5
Ecosystem service	82	79	23	16	33	2	2	1	2	2	2	2
Environment	1178	1032	549	490	260	58	72	36	11	43	18	25
Natural resource	334	323	143	71	80	18	34	8	3	14	4	14

Table C. 7. Environmental and social valuation keyword search within references

Environmental characteristic	Total	participatory	deliberative	Discourse	Visual	survey	questionnaire	focus group	citizen* juries	Health	DALY	QALY	Q methodology	expert panel	Delph	Systematic review
Air	69		1	1		20	4			18					2	
Climate	73	1				15	2			5						
Global warming	13					2										
Atmosph	20					5	2			2						
Carbon	81	1				8	1			4					1	
Land	819	10	2	1	12	200	32	5		32	1				1	
Wetland	134	2				37	4	3		4						
Woodland	59	2				19	6	2		4						
Soil	135	2			2	29	3			6						
Peat	6					2	2	3								
Landscape	220		1		10	66	13			12					1	
Beach	29				1	17	5			2						
Coast	86	1			2	37	4			8	1					
Water	560	10	1		2	179	32	5		47	2			1	1	
Marine	50	1				22	3			5						
Sea	135	3			2	53	10			10						
Biodiversity	250	11	2	1	2	52	16	5		16					1	
Animal	130	2	1		1	51	6			14						
Fish	174	3				76	7	1		13	1					
Plant	295	10			3	69	19	4		18	1				1	
Fauna	14					3				1						
Flora	12					3										
Fung	18	1			1	7	2			4						
Forest	997	19	1	1	12	233	63	12		30				1	2	
Micro	37	1			1	10	1			4						
Agricultur	578	6			4	152	25	10		30	1				1	
Crop	174	7		1	1	52	5	1		12						
Livestock	83	2				20	5			8						
Food	343	8			2	149	23	6		64						
Human	150	3	2	1	2	31	11	3		52	1					
Recreation	599			1	4	236	54	4		21						
Touris	253	1			3	109	28	3		13	1				1	
Fishing	73	2				38	5			4						
Hunt	79					34	7			2						
Amenity	201				5	62	16			7						
Aesthetic	56		1		4	21	3	1		3						
Conservation	603	15	2	2	3	191	40	8		19					1	
Ecological	242	4		1	1	46	11	3		15					1	
Energy	47	2			2	12	1	1		6						
Power	65				1	12	3	1		3						
Wind	17				1	2										
Biofuel	3					1		1								
Renewable	20	1			1	2	1	1								
Pollut	189	2				61	8	3		30	1				2	
Mining	13					5	3									
Mine	18					6										
Geol	4					2										
Ecosystem	254	5	4	3	1	54		3		19				1	2	
Ecosystem service	82		3	1		14		1		5				1	2	
Environment	1178	19	6	3	10	360	76	19		83	2				2	
Natural resource	334	8	2	2		87	17	2		16	1				1	

Table C. 8. Environmental and social valuation keyword search within references

	Total	cost*benefit analysis	value*benefit analysis	cost*effectiveness analysis	multi*criteria analysis	life*cycle analysis	risk	uncertainty	sensitivity	Score	Rank
Air	69	9	2	1			7	3	2		3
Climate	73	7	1				5	3	2	1	1
Global warming	13	2					1	1	1	1	
Atmosph	20						4	3	1		
Carbon	81	13	4		1		5	3	1	1	4
Land	819	73	18	2	1		39	12	10	8	17
Wetland	134	15	4		2		1	2	2	2	4
Woodland	59	6	1	2			2		1	2	2
Soil	135	8	1		1		8			1	3
Peat	6	1									
Landscape	220	26	9	1			11	1	3	3	8
Beach	29	2	1				3	2		1	
Coast	86	9	2		1		4	2	1		1
Water	560	57	10	1		1	32	8	13	2	12
Marine	50	4	1		1			1			1
Sea	135	7	3				7	5	1	2	5
Biodiversity	250	30	9	3	2	1	19	9	3	4	10
Animal	130	11	1				7	3	2	2	1
Fish	174	14	1				9	3	2		2
Plant	295	20	2	2		1	19	8	1	9	10
fauna	14	1	1				3	1	1		1
flora	12	2	2				2				1
fung	18	1					1		2		
Forest	997	86	16	3	2		53	24	16	8	28
Micro	37	4	1				4	2		1	
Agricultur	578	38	6				45	10	4	1	7
Crop	174	8	1				26	3	1		3
Livestock	83	4					5	1			
Food	343	8	1				56	9	5	7	7
Human	150	14	7		2		22	3	1	2	4
Recreation	599	34	10		1		12	7	8	2	17
Touris	253	15	1		2		3	3	2	2	10
Fishing	73	4					2	2	2		
Hunt	79	4					2	2	1	1	2
Amenity	201	12	8				7	4	1		3
Aesthetic	56	2	1							2	2
Conservation	603	77	16	3	2		30	25	7	11	18
Ecological	242	27	8		5	1	11	5	1	3	11
Energy	47	4	1			1	6			3	2
Power	65	7	1			1	5	2	1		1
Wind	17	2					1				
Biofuel	3						1				
Renewable	20	2				1	2	1			1
Pollut	189	21	1	1			22	5	4	1	1
Mining	13	1									
Mine	18	1	1		1		1				
Geol	4	1									
Ecosystem	254	22	7	2	3		13	6	3	3	7
Ecosystem service	82	6	2		1		4	2	1	1	3
Environment	1178	129	29	3	4	2	80	34	20	9	21
Natural resource	334	36	10		2	1	22	13	5		3

Table C. 9. Respondent view on stakeholder interest and influence in valuation

Stakeholder names		(blank)	Slightly influential	Moderately influential	Influential	Very influential	Extremely influential
AHRC/EPSRC Science and Heritage Research Programme	Extremely interested				1		
AONB offices						1	
Association of Gardens Trusts			1				
CPRE				1			
Defra						1	5
English Heritage					1		
Environment Agency							1
Garden History Society			1				
Historic House Association					1		
JNCC						1	
Local authorities						1	
Milk Development Council					1		
Ministry of Fisheries and Marine Resources							1
National Trust						1	
Natural England						1	1
Non-profit Land Trusts			1				
Proprety owners organisations					1		
scientists				1			
The Nature Conservancy							1
Water companies						1	
Academics	Very interested				1		
CLG						1	
Defra						2	
Direct resource users							1
Environment Agency						1	
European Union					1		
farmers							1
Fishing companies						1	
Forestry Commission					1		
Government bodies dealing with natural resource issues						1	
JNCC						1	
Natural England						1	
Scottish Natural Heritage		1					
SEPA		1					
United States Department of Agriculture							1
United States Fish and Wildlife Service						1	
Welsh Assembly Government						1	
WWF						1	
CABE	Interested					1	
Defra			1				
General Public				1			
LBAP				1			
Local authorities						1	
Natural England			1			1	
Professional institutes					1		
Royal Horticultural Society					1		
Defra	Moderately interested			1			
FAO						1	
World Bank							1
World Wildlife Fund				1			
Cairngorms National Park Authority	Slightly interested	1					
CLA			1				
Defra							1
Government departments							1
NFU			1				
RSPB		1					
farmers	Not interested		1				
Department of Agriculture	(blank)	1					
Environmetnal protection Agency		1					
EU land use and habitats policy departments		1					

Appendix D : NRES Valuation Methods

This summary of valuation methods is adapted from Eftec 2006, "Valuing our Natural Environment," supplemented by other sources. It briefly describes the main economic and deliberative valuation methods and some advantages and disadvantages associated with these different methods.

Economic methods

Market price proxies

Market price proxies use the prices that can be observed in markets to value environmental goods and services, for example, opportunity costs or the costs of alternative provision, mitigation costs, avertive behaviour and shadow (or alternative) project costs. For example, the value of the protective benefit of a wetland for flood defence can be determined through the cost of manmade flood defences of equivalent capability. Although market price proxies can be used for direct- or indirect-use value, they cannot be used for non-use values and do not determine consumer surplus. Often they provide only a partial value of the benefit of a particular resource and, in addition, market prices are often distorted through government interventions.

Production function

Production function methods rely on determination of the relationship between ecosystem goods and services and a marketed product and are used to capture indirect use value. For example, the value of air quality could be determined from its effect on agricultural or forest yields. Such methods, however, require considerable data and expertise to determine how particular environmental goods and services affect production. Often, it is extremely difficult to separate the effects of different environmental factors on production because of a lack of data and scientific uncertainty regarding the provision and interaction of ecosystem goods and services.

Hedonic pricing

Hedonic pricing uses market prices, most commonly property prices to determine the value of environmental characteristics that constitute part of the demand function for a marketed product or property. For example, the benefit of having access to a beautiful view is likely to increase property prices while the view of a slag heap may reduce the value of property. Hedonic pricing is limited to valuation of direct and indirect use values. Disadvantages of the technique include the large amount of data that are required on property prices and housing characteristics and the expertise required to understand and interpret results from a hedonic pricing model.

Travel cost method

The travel cost method uses costs, such as travel costs, entrance fees and time incurred in visiting a particular site for recreation, as a proxy of the recreational value of that site. It is used to develop demand curves for the site from which consumer surplus can be estimated. However, it is limited to valuing direct non-consumptive use values of resources that have specific recreational benefits, such as forests, wetlands, national parks, coastal areas. Non-use value cannot be estimated through this technique and would have to be calculated separately if it was necessary to include non-use values in the overall outputs from a project. Also, benefits or disbenefits that visitors are not aware of will be excluded in the final valuation.

The travel cost method has been further developed in order to assess the value of changing the quantity or quality of an environmental characteristic of recreational sites. The random utility model is an extension, often combined with the original methodology to explain individuals' choices between different sites as well as total recreational value of different sites. The random utility model is limited to valuing direct non-consumptive use value of resources that have specific recreational benefits, such as forests, wetlands, national parks, coastal areas and has the same other

advantages and limitations as the standard travel cost method.

Contingent valuation

Contingent valuation is a survey-based approach that constructs hypothetical markets to determine individual willingness to pay for environmental goods and services using a questionnaire. These are typically presented as bundles of benefits and values since eliciting individual goods and services and different types of value is often impractical. It is worth noting that stated preference methods such as contingent valuation and choice modelling are the only methods that can be used to estimate the non-use value of environmental goods and services. The contingent valuation method can be used to estimate many goods and services, including changes that have not yet occurred. However, it can be time-consuming to develop, implement and analyse. As with all valuation method, contingent valuation is limited by participants' knowledge or what they can be taught (hopefully without creating bias) during the period of the survey.

Choice modelling

Choice modelling uses the level of attributes of resources to reflect the flow of goods and services from those resources. It uses a questionnaire approach to present different combinations of these attributes to respondents who select their preferred combination or rank them according to their preferences. Each attribute combination has a price and analysis of the results is used to determine their willingness to pay or their willingness to accept compensation for the attributes that have been presented. Choice modelling can be used to estimate the total economic value of goods and environmental services and also to predict the value of potential changes in quality or quantity. It is more flexible than contingent valuation as a wider array of choices can be presented to respondents. However, the method can be time-consuming to develop, implement and analyse. The method is limited to what participants know or can be taught (hopefully without creating bias) during the period of the survey. Goods and services are defined in terms of their attributes, so it is possible to separate the value associated with each of these, although in practice, it is difficult and is rarely done. Although many combinations of attributes can be presented, respondents may find it difficult to discern preferences between the available options, leading to inconsistent responses, and this may need to be overcome by increasing the sample size and limiting the number of questions that each respondent has to choose from.

Deliberative and participatory methods

Survey approaches

In theory a survey could be used to ask respondents about any good or service. Some economic methods in fact rely on surveys and questions can, therefore, be used to elicit monetary values or indeed other quantitative or qualitative descriptions of value. In practice, surveys are best suited to broad scoping, since detailed questionnaires are unlikely to provoke much feedback because of complexity or time constraints.

Focus groups

Focus groups can be used in many different ways. They can also be used to consider any element of ecosystem goods and services, for example, by providing weights or scores on benefits from goods and services. They may also used to determine how people think about environmental goods and services and to consider a discourse on complex environmental issues, conflicts and trade-offs. Often, they are used during initial development of other social or economic methods and to elicit weights in Multi-Criteria Analysis. Focus groups may provoke antagonism between individuals or groups with conflicting resource interests and it may be preferable to avoid using them when such circumstances are known to exist.

Citizen's juries

Citizen's juries are used to capture social or public "values" rather than private values on the consumption of goods and services. Jurors may be selected to represent different viewpoints or stakeholders and citizen's juries operate by obtaining carefully considered public opinion on different options, soliciting evidence from a wide range of stakeholders, including expert opinion, during deliberations. They are generally used in complex resource issues that require exhaustive deliberation and have widespread public implications, for example, GM crops or nuclear waste disposal. However, it may be difficult to obtain a representative sample of jurors and citizen's juries are labour intensive and expensive as both jurors and witnesses must be compensated for their time.

Health-based methods

Health based methods measure the impact of an alteration to the flow of ecosystem goods and services on health, in terms of both quality of life and life expectancy. They can be used to value the impact of ecosystem goods and services in any situation where natural resources may affect human health. For example, they could be used to value the impact that an increase or a decrease in air or water quality might have in terms of quality-adjusted life years (QALYs), disability-adjusted life years (DALYs) and healthy life year equivalents (HYEs) in the relevant population. The value of alterations to the flow of ecosystem goods and services can be determined by ranking the magnitude of the effect on the health-based measure. However, deriving such values is complex and requires specialist knowledge and the link between alterations in the environment and health impacts are complex and not always known.

Q-methodology

Q methodology is a survey-based approach that attempts to understand how patterns of values and perceptions on the environment that are shared. As such it is generally used in the initial scoping stages of environmental valuation, rather than to elicit quantified values themselves. However, implementing Q methodology is relatively time-consuming as a structured sampling approach and detailed questionnaire are required.

Delphi survey and systematic reviews

Delphi surveys produce summaries of expert opinion and scientific literature on particular environmental goods and services and are used where circumstances are complex or specialised, where a wide range of expert opinion and literature needs to be assessed and where there is no other knowledge other than expert opinion, rather than as a means of deriving valuation data. While Delphi surveys tend to be used to summarise expert opinion, systematic reviews are used to gather an evidence base from the literature.

Appendix E : Non-monetary valuation methods

Monetary valuation methods have received increasing research attention in the past two decades. There has been a certain frustration in some quarters that although useful, monetary valuation takes a narrow view of human value and the different methods of valuation make a range of assumptions that do not reflect actual human behaviour and as such can lead to misleading valuations of environmental goods and services.

The methods' of Environmental valuation treat human value as utilitarian, where value is derived from the consumption of goods and services and can be measured by what humans give up (expressed in monetary terms) in order to obtain these goods and services, or accept in compensation for their loss. Following this logic, environmental goods and services will be allocated to those who have the ability to pay for them, or those that hold the legal entitlements to environmental goods and services. Clearly, this is at odds with a democratic system, where often a government is elected to ensure a fair and equitable distribution of wealth. Environmental valuation methods' also make certain assumptions over human behaviour. For instance, humans are assumed to have a complete set of preferences so they can judge how much they would be willing to give up for any set of goods and services, including environmental and social goods. Furthermore, they assume that humans make consistent, rational decisions based on perfect knowledge. In economic models humankind comprises incredibly complex people living in a simple world, whereas it may be argued that we are in fact simple people living in an incredibly complex world (Beinhocker, 2007).

There are of course other views of human value that exist outside of neo-classical economics. O'Neill (1993) suggests that to truly value something is to refuse to quantify that value in monetary terms. For instance, we cannot place a monetary value on the worth of our friends and family, so his argument goes; therefore, we cannot place monetary values on the environment, as it is central to the well-being of society. Sagoff (2004) adds to this argument by stating that market and social goods and services cannot be directly compared. He gives the examples of comparing the market value of daydream ridge at "Dollywood", the Dolly Parton museum and Cemetery ridge at the Gettysburg battlefield. Although both there to satisfy demand from the public, Dollwood is a money making enterprise, Gettysburg is visited by those who wish to respect the memory of those who fought there: a moral, social good. Thus, Sagoff argues that the value derived from each site cannot be compared.

From these objections, methods have been developed based on different assumptions of human behaviour and different social systems. Arguably the main alternative to monetary valuation and cost-benefit analysis is the range of methods that can be broadly classified as Multi-Criteria Decision Making (MCDM). MCDM methods are typically used to find solutions to problems, characterized by multiple alternatives, which are usually conflicting, for instance, development and conservation (Ceballos-Silva and López-Blanco, 2002). Crucially, MCDM techniques differ from valuation techniques in that they avoid reducing a problem to a single net present value, which assumes that decision-makers have a mono-dimensional utility function, dependent only on the economic elements of the resource allocation problem (Romero and Rehman, 2003). Instead MCDM assumes that decision-makers select projects or policies subject to multiple objectives and goals (Jones *et al.*, 2002).

Thus, MCDM methods differ from valuation in that MCDM methods treat utility as a composite of several attributes upon which decision-makers place value. The aim of MCDM methods is then to maximise delivery of multiple attributes, where the delivery of each

attribute is measured in their natural units (e.g. tonnes of pollution, hours of leisure, financial cost) rather than an overall single net present value. For instance, valuation uses money as an indicator of welfare, whereas MCDM techniques generally use preference scales e.g. a scale of 1-9 where 1 equals least preferred and 9 equals most preferred options.

Because there is no need to make all quantities commensurable, most MCDM methods are capable of handling qualitative and quantitative data. Thus, MCDM is more accessible and transparent to participants and does not entail abstract concepts such as valuing an environmental asset in monetary terms. This structure of requiring issues to be weighted can also be combined with a discourse between stakeholders; so MCDM facilitates more engagement with affected parties than CBA.

However, the ability of MCDM to take account of a wider range of impacts and elements of value is a product of its looser theoretical structure. Environmental valuation is based on more than a century of research in welfare economics. Thus, it could be argued that valuation has a higher degree of internal consistency than MCDM. Furthermore, it has been argued that because valuation studies use a common unit of value, the impact of different projects in different areas can be broadly compared. This is not the case for MCDM, where the weighting system used in one project is not directly comparable with that used in another. Therefore, an accumulation of experience could make benefit transfers increasingly useful for decision-makers; whereas a similar MCDM related method would not be possible.

Where data are not available, or it is felt that expert opinion is more desirable than consumer response, the Delphi approach is available. The Delphi technique in its original form was designed for forecasting future conditions and estimating unknown parameters. It has been used in a variety of study areas such as, planning, environmental impact assessment, social policy and public health, predominantly as a method for structuring group communication so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem.

The Delphi technique involves the use of a panel of experts, who answer iterative rounds of questions. These questionnaires are completed anonymously so respondents are free from any negative group dynamics. All responses are shown to every respondent, with a view of then determining whether any respondents will change their view in light of evidence from other experts. This enables respondents to change position and compromise over some issues. The results can be quantitative forecasting or qualitative discussion. But generally the technique is used to gain a consensus on technical issues by a group of experts where there is uncertainty, insufficient data or incomplete theory, where a random sample may be unable to handle such complexities.

Some proponents of the Delphi technique claim it is most effective in areas of high uncertainty, lacking in any substantial empirical data, where more scientifically rigorous techniques are not applicable (Rowe and Wright, 1999). On this basis, the Delphi technique can inform the decision-making process where there is limited empirical data (Angus *et al*., 2003).

There are inherent drawbacks of using the Delphi technique. One such drawback is that it is extremely difficult to determine the validity of the technique's processes. In order for a Delphi study to obtain high content validity a study must ensure an honest expression of views by respondents, and facilitate an accurate discussion of the issues. Validity is however, difficult to determine; for instance laboratory experiments with the technique are impossible,

as experts will vary from study to study and time to time. Because it has been difficult to judge the usefulness of Delphi, it has been accused of lacking scientific rigour (Hasson *et al.* 2000). Although the Delphi technique is apparently useful for solving a range of problems, in reality it is difficult to gauge the validity of these results as it is applied to uncertain hypothetical situations.

From this brief review of non-monetary environmental valuation methods it is clear to see that there are some useful alternatives, but none are without their drawbacks. In this respect they are much like monetary environmental valuation techniques. Each method has its own strengths, weaknesses and analytical niche. The techniques described are not complete substitutes to monetary valuation. This suggests that as a first point of entry into a study, there is a need to assess the appraisal problem at hand and to carefully select the appropriate method for valuing the environment. Even better, it makes sense to pair monetary and non-monetary appraisal to better understand the problems, issues and social context of what are complex environmental problems.

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Appendix F : Environmental Valuation: Effectiveness in Practice

Compared with the burgeoning literature on the refinement of environmental valuation methods, relatively little effort has been applied to determine the usefulness of their results and whether their outcomes have made a difference to policy decisions or legal proceedings.

This section will explore the way in which methods of environmental valuation have been used as a policy-support tool or as a means of justifying legal action against stakeholders that have harmed the environment.

In the EU policy-makers have largely avoided the use of environmental valuation as a basis of decision-making. Instead environmental regulations have tended to set ecological standards, which should be met at the least compliance cost. For instance, both the Integrated Pollution Prevention and Control (IPPC) and the Water Framework Directives (WFD) use Cost-effectiveness Analysis to determine the least cost way of meeting mandatory standards (Morris, 2007). Only where the costs of abatement, under these regulations, are likely to exceed the environmental benefits has there been any scope for environmental valuation, although this has not been used in practice. Instead the benefits of pollution reduction have been defined as positive effects that are valued in the market place. For instance, the saved costs resulting from a reduction in dredging activities through sediment abatement.

The environmental liability directive was widely anticipated to open the way for environmental valuation to directly inform decision-making. This Directive encompasses any damage to protected species and natural habitats, damage to Sites of Special Scientific Interest (SSSI), damage to water and land damage. The Directive requires those operators that cause damage to the above environmental assets to reinstate them back to their quality before the damage occurred. Here the role of valuation was perceived to be as a tool of calculating the damage caused by the perpetrator and by implication, how much they should be charged for compensation and remediation. To date, as with other Directives perceived to give a role, environmental valuation has not been used as a basis of bringing charges against a polluter and it remains unclear how successful such an action would be.

Valuation has been used, and this was supported by evidence from the survey, to support policy decisions. However, it is unclear to what extent these values influence policy-makers, or whether they are used as supportive evidence, rather than being central to a decision. Often the policy formulation stage is opaque. To determine the usefulness of valuation in a policy context would require a survey of policy-makers, which goes beyond the scope of this study. What is clear is that Governments' within the EU perceive valuation to be an effective tool for environmental protection and justice. What is not clear is how these tools will perform in practice.

Although the EU has largely avoided use of valuation to support policy, the US has been more amenable to its use, particularly in the court of law. Therefore, it is useful to review the experience of the US in order to determine how valuation could be used in the EU.

The US has well-established liability laws, which requires any damage to public resources to be remediated. The costs of remediation are based on rehabilitating the damaged environment, the loss of value associated with natural resources pending recovery of the environment to the baseline level (including lost social value) and the costs of assessing and reporting damage.

This legal framework gave a role to environmental valuation methods, particularly in measuring the loss of non-use value, as there an otherwise complete lack of techniques to quantify these types of losses. This led to high profile studies into the loss of non-use value associated with environmental impacts, such as the contingent valuation of the lost passive (non-use) value resulting from the Exxon Valdez oil spill in Alaska, reported by Carson *et al*. (2003), which was undertaken to determine how much compensation should be paid to the people of Alaska and beyond as a result of the oil spill. Several other studies followed looking to calculate non-use value, mostly based on the contingent valuation technique. However, these have rarely been the decisive evidence used in court, indeed damages were agreed out of court for the Exxon Valdez case, far below the amount suggested by the contingent valuation study.

US authorities were quick to establish the reliability of environmental methods. The National Oceanic and Atmospheric Administration (NOAA) commissioned a panel of Nobel Prize winning economists to develop a code of best practice for undertaking a contingent valuation. This was recognised in law: any study following this code of practice would produce robust results. Given this robustness, the use of this method was not contestable in court; only how the study was undertaken could be contested, particularly if the researchers deviated from the code of best practice.

Although environmental valuation has a strong basis for use in court, its use has sparked debate on whether such values are consistent with law. In a review of this debate Swanson and Kontoleon (2002) highlighted the areas in which valuation is inconsistent with value as stated in law. For instance, a problematic issue arises over the population that should be compensated as a result of environmental damage, particularly where there has been a loss of non-use value. Damage in law tends to mean parties who can demonstrate a loss or infringement of their property rights, which can be compensated. In economics damage is a loss of welfare to any individual as a result of the environmental degradation. This leads to very different estimates of compensation. As an example, in the Exxon Valdez study used the entire population of the USA was held to have been impacted, a far greater number than those who could demonstrate that they had been directly damaged by the oil spill.

A further issue arises surrounding an individual's prior knowledge of benefit flows from an environmental good. Most stated preference studies make sure the respondent understands what they are valuing, providing information on what has been lost, before the valuation exercise begins. It can be argued that in the absence of this knowledge the individual would have been unaware of any damage and furthermore, by not pursuing this knowledge in the first place has little regard to the actual loss. Thus, non-use value departs from the definition of damage in tort law. Stated preference studies value damage after an event and so do not capture the pre-existing values independent of the surveys information. On a more practical basis the costs of valuation sometimes preclude its use on the cost-benefit principle, where the costs of undertaking a valuation study would outweigh the likely compensation won in court.

These issues have proved difficult. Because of this, environmental valuation tends to be used where there are no other alternatives capable of measuring lost value. In most applications the preferred form of valuation are those methods that define resource-to-resource, or service-to-service compensation, which is more compatible with tort law. In this context Habitat Equivalency Analysis has been used to determine the area of sensitive habitat lost and how much it would cost to replace this habitat, including years of lost services, as the new habitat grows to the stature of the old. This method was used to determine the compensation due for

the destruction of 1.63 acres of sea grass within the Florida Keys National Marine Sanctuary by treasure hunters seeking to recover gold from a wrecked Spanish galleon. The treasure hunters were brought to court in 1997 and HEA was used successfully to win over $500,000 in damages to repair the habitat (Fonseca *et al*. 2000). It is these market, or cost-based methods that have become more favoured, rather than the demand based estimates of valuation. This is in stark contrast to the weight of research effort, which is largely behind development of demand based methods.

From the US experience it appears that more attention is required to understand how environmental values link to legal definitions of damage and compensation, in order to make valuation consistent with legal processes. The extent to which valuation is used in policy is as yet unclear, but should be an area for further study.

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Appendix G : Valuation and soils

Science Challenge 4 sets itself the task of considering how the non-market benefits provided by natural capital can be incorporated in decision-making. The ecosystems framework (e.g. de Groot *et al*., 2002, 2006) is useful as a device for framing the range of benefits that need to be considered. The ecosystems framework has been adopted by statutory bodies in the form of Public Service Agreements such as the one held by Defra on the natural environment, in order to deliver against this agreement, Defra is "committed to developing a more strategic framework for policy-making and delivery on the natural environment, based on the principals of an ecosystems approach" (Defra, 2007b). The steps required to value ecosystem services are mapped out in Defra's "impact pathway approach to valuation of ecosystem services" (Defra, 2007a). NERC might consider a similar approach in respect of the resources that are covered by the SUNR Science Challenges. Here we examine the particular case of soil.

Relatively few studies have been undertaken to specifically quantify the non-market benefits of soil to society. However, from a perusal of the keywords associated with the references in the CAB Inventory, it is clear that the valuation of soil is often associated with other resources (Table G. 1). Soil is fundamental to many ecosystem services and valuation must therefore encompass its impact and on other resources. In other words, the social value of soil cannot be determined without also understanding the social value of its impact on water storage and flood regulation, fertility provision, pollution attenuation, sequestration and so on. It is such broader interconnections that the ecosystem framework can help to clarify.

Much of the literature values the welfare provided by soil as a result of research on other natural resources. For example, Yun *et al*. (2008) valued the impact of restored secondary forest in part of Guangxi Zhunang, China since 1981, providing a social value for the role that this played in helping to maintain soil fertility and prevent soil erosion. This value was found to far exceed the direct value associated with timber, herb and fruit extraction. A study by Bofu *et al*. (2008) on the Lugu Lake watershed concluded in similar vein, that the benefits provided by regulating services such as oxygen provision, carbon sequestration, and soil and water conservation greatly outweighed the production benefits from the watershed. Some literature argues for careful accounting of the services derived from soil and a synthesis of approaches and data between different national institutions to prevent double accounting and confusion (Tzschupke, 2008). Other literature presses for soil conservation in sensitive areas using the argument of greater social well-being to justify the investments that would be required. For example, Thomas (2008) proposed that rangeland soils in Asia and North Africa could provide water, biodiversity, and carbon sequestration benefits if payment was forthcoming for these environmental services. A further segment of the literature has tried to determine the value of agricultural soils. Williams *et al*. (1993) attempted to determine the farm value of topsoil in spring wheat production areas of Montanan, USA and Alfsen *et al*. (1996) attempted to determine the cost of soil erosion to Nicaragua, in terms of lost productivity and the changes that this would make to patterns of imports and exports, and rural employment in agriculture.

Despite their importance, it has been suggested that soil degrade because markets fail to account for the social cost of poor soil management as well as the non-market benefits provided by soils. For example, Huguenin *et al*. (2006) discussing soil fauna, which "enhanced soil drainage, creating passages for roots, aerating the soil, and recycling organic matter and nutrients", stated that since these benefits were not represented in markets, they were not protected. Indeed, they concluded that private human activity would therefore

continue to harm the soil environment, ecosystems, and social welfare, because these externalities were not accounted for.

Table G. 1. Keyword search associated with references that included "soil" in the abstract or subject heading of the inventory

Resource or service keywords				Economic method keyword		Decision support systems	
Key word	No	Key word	No	Key word	No	Key word	No
Air	11	Crop	25	Valuation	123	cost*benefit analysis	8
Climate	17	Livestock	5	Contingent valuation	36	value*benefit analysis	1
Global warming	1	Food	3	Willingness to pay	29	cost*effectiveness analysis	0
Atmosph	5	Human	12	Non-market benefits	27	Multi*criteria analysis	1
Carbon	20	Recreation	20	hedonic	8	life*cycle analysis	0
Land	72	Touris	9	travel cost	3	Risk	8
Wetland	10	Fishing	2	stated preference	5	uncertainty	0
Woodland	3	Hunt	5	revealed preference	1	sensitivity	0
Soil	135	Amenity	7	benefit* transfer	6	Score	1
Peat	0	Aesthetic	5	production function	2	Rank	3
Landscape	15	Conservation	51	market price	9		
Beach	1	Ecological	21	**Social method keyword**			
Coast	4	Energy	6	participatory	2		
Water	63	Power	2	deliberative	0		
Marine	2	Wind	4	Discourse	0		
Sea	6	Biofuel	0	Visual	2		
Biodiversity	23	Renewable	0	survey	29		
Animal	3	Pollut	29	questionnaire	3		
Fish	5	Mining	0	focus group	0		
Plant	20	Mine	5	citizen* juries	0		
Fauna	3	Geol	0	Health	6		
Flora	3	Ecosystem	25	DALY	0		
Fung	2	Ecosystem service	9	QALY	0		
Forest	51	Environment	55	Q methodology	0		
Micro	5	Natural resource	18	expert panel	0		
Agricultur	48			Delph	0		
				Systematic review	0		

In the UK, these problems have been apparent in peat soils, where many ecosystem goods and service are under threat. In pristine peat soils, the decay of organic material is relatively slow, but in their degraded state, this increases, leading to reduced carbon sequestration, or, in extreme cases, large losses of carbon through gaseous emissions as well as dissolved forms, and losses of particulate carbon through soil erosion. In Europe, 100,000km^2 of peatland has been lost and the remainder are under threat (Rawlins and Morris, 2008). In the UK Fens, an estimated 16% of the peat stock recorded in 1850 remains and much of the remaining stock will be irreversibly degraded in the next two to three decades (Oats, 2002) and in the Somerset Levels, there has been extensive subsidence and shrinkage estimated to be 1 to 1.5 cm per year (Brunning, 2001).

Despite this, the importance of UK peatland for storing carbon is still significant. Reducing carbon losses through restorative efforts could have many benefits - for example, carbon sequestration for climate regulation. Such sequestration could be translated into carbon offset equivalents, and therefore given an economic value. For other stakeholders, such as water companies, the potential economic gains of an improvement in peatland regulating services are more directly observable through lower operating costs due to reduced soil erosion. Peatlands are also important for their cultural and habitat services. They play an important part in the aesthetics of the landscapes, people's identity, and sense of naturalness and are

major habitats for threatened species of animals and plants. The extent to which they evoke these sentiments is likely to influence the value placed on them.

Table G. 2. Peatland goods and services identified by stakeholder of the Somerset Moors and the Anglian Fens (Source: Rawlins and Morris, (2008).

Peatland Function		Peatland Use	Dominant Stakeholder Interest
Production	Food production through the conversion of solar energy into edible plants and animals and their products	Agriculture – arable, dairy, beef.	Farmers, RDS, Defra, IDBs
	Conversion of solar energy into biomass for human construction and other uses	Horticultural fertilizer	Extractors, CC
		Withy production	Withy growers
Regulation	Filtering, retention and storage of fresh water	Irrigation	Arable farmers
		Flood water storage	FDC, EA, IDBs
	Role of biota in storage and recycling of nutrients	Maintenance of water quality	EA, EN
	Role of vegetation and root matrix and soil biota in soil retention.	Maintenance of healthy soils and productive ecosystems	Farmers
Information	Aesthetic information through attractive landscape features	Enjoyment of scenery	Local communities
	Variety in landscapes with potential recreational uses	Tourism and recreation	LAMP, EN, RSPB, NT, WT
	Variety in natural features with spiritual and historic value	Preserved historic information in the form of peat and the structures or beings preserved within it	CC, EN, RSPB, NT, WT, RDS
Habitat	Suitable living and reproduction habitat for wild plants and animals	Conservation/restoration of species, habitats and ecosystems	EN, RSPB, NT, WT, EA
Carrier	Suitable space and subsoil for human habitation/construction	Development for housing or other buildings	Local communities, FDC
	Suitable space and conditions for terrestrial and non-terrestrial transport	Navigation via roads or waterways	Local communities, FDC

It is argued that one way to improve the management of natural resources such as peatlands is to give the various ecosystem goods and services a "value", so that informed management decisions can be made that include their non-marketed as well as their marketed benefits. Although the cost of developing values for such environmental benefits is high, it is argued that the cost of not doing so is higher (Eftec, 2006).

A recent ADAS report (ADAS, 2006) commissioned by Defra attempted to value the "monetary" benefits of soils services in terms of: i) carbon storage and sequestration, ii) water storage and flow mediation, iii) nutrient cycling and crop production, iv) supporting construction, v) natural attenuation of pollution and contamination, vi) archaeological and landscape heritage protection and vii) support of ecological habitat and biodiversity.

Carbon storage and sequestration

Globally, soils contain approximately twice the carbon that is stored in the atmosphere. In the UK, peat is the most important store of soil carbon. However, this is greatly threatened by agricultural use in the lowlands and by drainage of upland peatlands for citing wind farms. The ADAS report provided a wide range of values for the social cost of emitting carbon, ranging from £35 to £140 t^{-1}. Given a social cost of £70 t^{-1} used by the UK government, the value of carbon sequestration in land converted from arable use to permanent woodland or biomass production was estimated to be about £110 ha^{-1} a^{-1} and a change from grassland to

woodland was even greater (£302 ha^{-1} a^{-1}). The social cost of carbon losses from highly organic soils was found to be high, ranging from £105 ha^{-1} a^{-1} from drained upland peat to £882 ha^{-1} a^{-1} for lowland peat, often exceeding the benefit from the agricultural or forestry land use which caused the peat loss in the first place (ADAS, 2006).

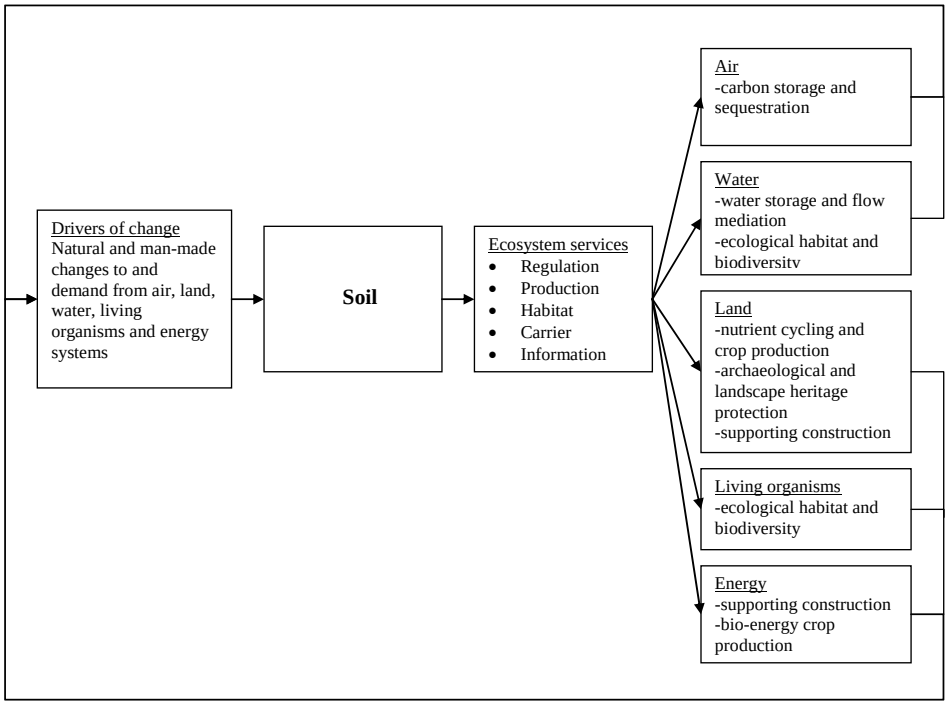

Figure G. 1. Schematic representation of ecosystem services provided by soils and their importance to other resources

Water storage and flow mediation

The report goes on to note that the value of the soil in water storage and flow mediation is significantly changed as a result of uses that impede infiltration, because of surface compaction or capping from urbanisation or poor rural land management.

The main social benefit of water storage and flow mediation is reduced flood risks and this can be valued in terms of "public willingness to pay for averting increased flood risk", for example using "the cost of mitigation to reduce flood risk."

Nutrient cycling and crop production

Nutrients are provided by atmospheric deposition, N-fixing soil bacteria, and mineralisation of organic matter. The value of this was found to be substantial. In a grass sward managed to contain white clover, the replacement value of N-fixation was approximately £86 ha^{-1} a^{-1} (assuming £150 t^{-1} N fertiliser). Lost production estimates indicated that there was a high cost to letting the soil degrade. For example, the cost of deviating from best management practices resulted in yield losses that in production terms were worth from £19 ha^{-1} to £960 ha^{-1} for UK crops. The cost of allowing pH to drop from 6.5 to 5.0 ranged from £70 ha^{-1} to 300 ha^{-1} and soil compaction was estimated to cost about £159 ha^{-1} for sugar beet.

Supporting construction

Variation in the ability of the soil to support construction had little impact on land values, reflecting the high premium on development land in comparison with other land uses and the relatively low impact of different soils on costs of development, except where access is a major cost. It is worth bearing in mind however, that urbanisation greatly alters the ability of the soil to provide other ecosystem benefits, in terms of water storage and flood abatement, attenuation of pollutants and contaminants and support of biodiversity.

Natural attenuation of pollution and contamination

Soils attenuate pollutants through adsorption and degradation of the contaminant to less toxic compounds. They can attenuate the impact, for example, of heavy metals, pesticides, phosphorus, sediment, pathogens, nitrate and acid deposition. However, this is a complex process likely to be affected by many factors such as good soil structure, levels of soil organic matter, clay content, microbial biomass and cation exchange capacity and changes in land use and climate. Predicting the rate of attenuation, degradation and pollution is complicated by the way in which these factors affect each other and the underlying science is complex and sometimes unclear. For example, understanding the attenuation of pathogens would require understanding not only of how the factors above affect attenuation, degradation and pollution, but also how pathogens affect health.

A particular difficulty lies in finding marginal values for water quality, since studies may be undertaken in the context of achieving particular thresholds that comply with regulation or notions of good water quality. Linking particular pollutants and contaminants to values is also difficult, since water quality is viewed as a bundle of benefits, rather than linked to particular contaminants. An alternative approach is to use the cost of abatement measures, applied for example to agriculture, to meet policy defined targets for water quality such as those defined in the Water Framework Directive. For example, a scheme for reducing N, P, and faecal contamination from farms devised by Cuttle *et al.* (2006) estimates the cost of reducing pollution from farms. The ADAS report suggests that this could be used to determine the cost to society of deviating from best management practice or achieving water quality standards. Whilst small reductions in losses are relatively inexpensive (reducing losses by 1 kg ha^{-1} a^{-1} was estimated to cost approximately £3 ha^{-1} a^{-1}), large reductions are substantially more expensive (reducing losses by 5 kg ha^{-1} a^{-1} was estimated to cost approximately £98 ha^{-1} a^{-1}).

On the whole, deviating from best management practices reduces the ability of the soil to attenuate pollutants and contaminants. This affects the well-being of a wide range of stakeholders, such as recreational users of water, water and electricity companies, and individuals who may be drinking contaminated water. The cost of these externalities to society varies widely. For example, deviation from best management practice could impose N and P attenuation costs that vary from £1.2 - £253 ha^{-1} a^{-1} depending on the degree of deviation from best management practice. Land use change can also impose costs for example changing from extensive grassland or setaside to arable may impose costs of between £12 - £159 ha^{-1} a^{-1}.

Archaeological and landscape heritage protection

Soils protect archaeological site and to artefacts. The ADAS reports suggests that society has a preference for preservation of heritage and culture and this is also demonstrated by planning regulations within the Town and Country Planning Act. The social value of the role that soil plays in preserving archaeological sites has not been determined, and only one study attempts to value willingness to pay for policy measures to protect archaeological heritage on farmland (Hanley, 1996). However, the ADAS report suggests that money devoted to protecting

archaeological sites on farmland within the Environmental Stewardship Scheme can be used as a proxy for public willingness to pay for preservation of archaeological sites.

Support of ecological habitat and biodiversity

The role of soil in supporting ecological habitat and biodiversity is crucial. Soil itself contains many important bacteria that are critical to the other services provided by soil, such as N-fixation, or attenuation of pollutants and contaminants. But soils are also the substrate for ecological habitats and biodiversity. These in turn command very high social value as valuation studies and policy and statutory guidelines can testify. A recent report by Jacobs *et al*., (2008) estimated that the landscape and habitat value of UK farmland to society was worth £845 million per year to society whilst the biodiversity value was worth £307 million per year. These benefits are compromised by poor management, leading to eutrophication, soil erosion or compaction, for example, resulting in air pollution or changes in plant communities. The degree of social value attributable to the role that soil plays within this is not well understood and indeed may be difficult to determine.

Information gaps

Several information gaps are reported by ADAS (2006). The authors suggest that there is a major challenge to be overcome in linking technical measures of water quality change to values and propose that new technical and economic measures may also be needed. They suggest that improvement in models and modelling is required to understand marginal changes in water storage and peak flow events in catchments, consequent to land use changes, for example, as a result of afforestation or urbanisation. Linked to this is the need for cost information for land uses under various scenarios and estimates of the benefits of reducing flood risks. The authors propose that understanding of the linkages between soil type, soil fertility and soil workability are needed, since these are not reflected in land values. A better understanding of the marginal changes in soil functions and the link with the provision of services from different soils is needed, for example, in terms of an increase or decrease in nutrients or attenuation of pollutants and contaminant loss from soils. The authors suggest that the current data are less then ideal for predicting across different scenarios of land use, soil types and climates, which therefore hinders valuation at a national level. Linkages between marginal changes in water quality indicators and public benefits derived from this need to be better understood and valued, implying a need for more research on public willingness to pay for measures to increase water quality. More research may also be needed on the social value of protecting archaeological sites and artefacts, pollution attenuation, habitat provision and biodiversity. Finally, the collection and development of environmental and social datasets for major policy objectives relating to soils would be useful with a view to outlining the research and data that needs to be collected for major policy objectives.

Appendix H : Web of Science 'exemplar' papers

The following is a summary of a selection of publications taken from Web of Science (http://apps.isiknowledge.com) that have been highly cited since their publication and thus may represent 'exemplar' studies in the field of natural resource valuation. The papers are structured according to broad natural resource studied, however the interaction of natural resources as ecosystem services and functions means that several of these papers appeared in more than one search and can not necessarily be classified into one particular category.

Water

Aldred and Jacobs (2001) describe what is thought to be the first citizens' jury (CJ) in the UK to directly address an environmental policy question, in this case, the creation of wetlands in the Fens close to Ely, Cambridgeshire. Issues are highlighted such as the problems in selecting membership of the CJs and participatory decision procedures on the whole in order to represent the various stakeholder interests whilst also capturing the demographic of the area being surveyed. Aldred and Jacobs (2001) suggest that a 'best practise' methodology for CJs may become unquestioned and "more prone to progressive capture by commissioning bodies". The authors comment on the role of the researcher in the CJ acknowledging that interventions, whilst essential, must not manipulate the process, drawing parallels with contingent valuation (CVM) researchers. They additionally discuss the need for information to be presented both verbally and in written form to ensure participants equal access, whilst providing sufficient detail to enable jurors to question the witnesses. Further comparison between CJs and CVM was made on the issue of representativeness and the authors suggest that although CVM has a much wider range of participants, they are often unable to express their views, particularly those that characterise environmental concern.

Blamey *et al*. (1999) similarly argue that CVM is susceptible to 'yea-saying', whereby respondents agree with the interviewer irrespective of personal views leading to "biased willingness-to-pay (WTP) estimates and reduced sensitivity to scope". Their study involves the evaluation of multiple water supply options in the Australian Capital Territory (ACT) considering attributes including increases in household water costs, restrictions on water use, water quality and impacts on habitat for rare and endangered species. For this they chose to employ the choice modelling (CM) technique stating it "better suited to the economic evaluation of multiple mutually exclusive policy options" and "less prone" to the limitations of CVM. They conclude that whilst choice modelling provides "a viable and flexible alternative to CVM" well suited to evaluating multiple alternative policy options, these multiple attributes bring much greater complexity to the undertaking of CM studies. However it was further noted that community ranking may be attractive to those who are "philosophically opposed to monetary valuation of the environment",

According to Turner *et al*. (2000), "wetlands are the only single group of ecosystems that have their own international convention". However, it is suggested that despite this and legislation at various levels, regulation still appears to be insufficient and that this arises from a "lack of understanding of the multitude of values that may be associated with wetlands" (Turner and Jones, 1991, cited in Turner *et al*., 2000). This failure of information is attributed to lack of understanding of wetland roles and functions on the part of politicians and the public in general and furthermore "indirect consequences of land use, water management, agricultural pollution, air pollution and infrastructure for the quality and sustainability of wetlands". The authors discuss that this may be due in part to the complex nature and 'invisibility' of spatial relationships between groundwater, surface water and wetland

vegetation reinforcing the need for an ecosystems approach to the valuation of such resources.

Turner *et al*. (2000) examine "the potential for systematic and formalised interdisciplinary research on wetlands". They suggest that lack of awareness of wetlands conservation has resulted in their low priority in decision making and consequent destruction or substantial modification of wetlands "causing and unrecognised social cost". The need for better integration between ecological science and economics is supported and described as "the essential link between wetland ecology or functioning and wetland economics and values".

"Wetlands are complex multi-functional systems and they are therefore likely to be most beneficial if conserved as integrated ecosystems…rather than in terms of their individual component parts".

"In order to make progress in the important work of building integrated models, natural and social science researchers should reach agreement on:

- terminology and typology appropriate to valuation;
- the scale of effects to be analysed and possible associated thresholds;
- valuation methodologies;
- links between valuation and systems and scenario analysis;
- the transferability of information and results in both the scientific and economic realm;
- the focus of the analytical approach, whether thematic or by site;
- consideration of valuation within its context, i.e. the prevailing political and social framework."

Source: Turner *et al*. (2000)

Pretty *et al*. (2003) consider the environmental costs of freshwater eutrophication in England and Wales, estimating the damage costs (both social and ecological) to be £75.0-114.3 million per year and policy response costs, to address this damage, to be £54.8m. They suggest that part of the problem is the lack of knowledge of ecosystem services and the consequences of these being diminished or lost. Pretty *et al*. (2003) suggest that WTP estimates or willingness to accept (WTA) compensation for loss/damage to a service provide the "best and most consistent way to estimate damage". The study used a wide range of published valuation studies that employ various valuation techniques. The study developed a cost category framework consisting of damage (or value loss) costs comprising both use and non-use values, and policy costs incurred in responding to damage noting that these costs are not additive because response costs are a measure of the amount spent on dealing with problems arising from eutrophication.

The uncertain nature of eutrophication leads to difficulties with valuation as the threshold at which nutrient enrichment causes damage is not known and furthermore varies with both location and time. In total sixteen cost categories were considered, split according to damage or response costs and the estimates produced suggested that previous studies had underestimated total costs. Uncertainties still exist due to gaps in knowledge and the authors highlight the "urgent need for greater analysis of representative catchments" for better understanding and the need for pilot studies on representative whole catchments or river

basins to "produce detailed nutrient budgets, predict eutrophication outcomes and estimate the costs and benefits of prevention and remediation".

Energy

From various searches, it does not appear that a great deal of 'exemplar'/widely cited valuation research has been conducted in the area of energy, or more particularly renewable energy in the UK. Much of this work appears to come from the US and Scandinavian/Northern European countries that have traditionally been more likely to embrace these technologies.

Alvarez-Farizo and Hanley (2002) suggest that the environmental costs of wind farms are highly case-specific and difficult to quantify. This study applied both choice experiments and contingent ranking to the valuation of environmental impacts of windfarms in Zaragoza, Northern Spain. The paper compared the implicit prices derived from the both methods, which was not thought to have been previously undertaken. It was found that choice experiments gave higher willingness to pay estimates than contingent ranking, this was thought to be because respondents did not pay as much attention to the price characteristic in the choice experiment study as in the contingent ranking study.

Living systems

Hein *et al*. (2006) suggest that "relatively little elaboration of the scales of ecosystem services has taking place", noting that spatial and temporal scales affect the values attached by different stakeholders. Hein *et al*. (ibid) examine the spatial scales at which ecosystem services are supplied for the De Wieden wetland in The Netherlands, analysing the values of particular ecosystem services supplied by the wetland and the scales at which these services are supplied to stakeholders. A case study area of approximately 5200 ha and four ecosystem services were selected representing a mix of services important to stakeholders at different levels. Different approaches to valuation were used for the four services owing to deficiencies in data. For example, nature conservation was valued using the travel cost method, while recreation used a net value added approach. It was suggested that whilst CVM is often used to assess non-use values associated with nature conservation, the validity of this may be questionable as "respondents do not actually have to pay the amount they express… for a service, which may lead to overestimation of its value". Hein *et al*. (2006) attempt to show how the values of the four services are distributed over four spatial scales, municipal, provincial, national and international, noting that "stakeholders at different scales often attach a different value to ecosystem services", depending on their cultural background, and the impact of the service on their income or circumstances. Hein *et al*. (2006) conclude that "it is crucial to consider the scales of ecosystem services when valuation of services is applied to support the formulation or implementation of ecosystem management plans" and suggest that a balancing of stakeholder interests at different scales is required. They further note the difficulties presented by monetary valuation of the nature conservation service at a global scale, particularly in finding benchmark against which to compare it.

Turner *et al*. (2003) attempt to critically review the literature on environmental evaluation of ecosystem services suggesting that studies valuing multiple functions and uses and those seeking to capture 'before and after' states are most important as to rational decision making in "ecosystem conservation versus development situation involving different stakeholders" compared to single function valuation studies that predominate the literature. The study highlights four areas of difficulty in valuation research as being: 1. marginality, 2. double

counting, 3. typological, 4 spatial and temporal issues and 5. distribution of benefits and costs, suggesting that "typically, though not exclusively, developing countries conserving ecosystems and biodiversity, incur high local costs for the sake of often large global benefits" in contrast to the relatively low costs and high benefits of developed countries whom, it is argued, should compensate those developing countries incurring losses from conservation policies that provide global benefits.

Air

The category of 'air' is a further example of the need for more detailed, context-specific keywords in searches for valuation research to reflect the interactions, services and functions provided by air within an ecosystem.

Many of the results related to air quality and human health, with some incorporating happiness' surveys or life satisfaction data (e.g. Welsch, 2006). Ready *et al*. (2004) consider the reliability of benefits transfer as applied to contingent valuation studies relating to willingness to pay to avoid ill health episodes in five different European countries. The study found that "there clearly do exist differences in WTP among the countries included" and pairwise comparisons showed "statistically significant differences in WTP to avoid the same ill health episode". Ready *et al*. (2004) however suggest that this does not imply that benefit transfer is impossible, but that errors will be involved of varying magnitude and that "a tradeoff must be made among the increased cost and delay associated" with a new study and an improvement in reliability relative to using benefit transfer. They furthermore suggest that the expected loss associated with making and incorrect decision should also be considered.

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