APPLIED ENVIRONMENTAL ECONOMICS

A GIS Approach to Cost-Benefit Analysis

IAN J. BATEMAN
ANDREW A. LOVETT
JULII S. BRAINARD

CAMBRIDGE
UNIVERSITY PRESS

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE
The Pitt Building, Trumpington Street, Cambridge CB2 1RP, United Kingdom

CAMBRIDGE UNIVERSITY PRESS
The Edinburgh Building, Cambridge, CB2 2RU, UK
40 West 20th Street, New York, NY 10011-4211, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
Ruiz de Alarcón 13, 28014 Madrid, Spain
Dock House, The Waterfront, Cape Town 8001, South Africa

http://www.cambridge.org

First published 2003

Printed in the United Kingdom at the University Press, Cambridge

Typeface Times 11/14 pt *System* LaTeX 2ε [TB]

A catalogue record for this book is available from the British Library

Library of Congress Cataloguing in Publication data

Bateman, Ian.
Applied environmental economics: a GIS approach to cost-benefit analysis / Ian J. Bateman,
Andrew A. Lovett and Julii S. Brainard; foreword by David W. Pearce.
p. cm.
Includes bibliographical references and index.
ISBN 0 521 80956 8
1. Environmental economics. 2. Environmental economics – Research.
I. Lovett, Andrew A. II. Brainard, Julii S. III. Title.
HD75.6 .B38 2002
333.7 – dc21 2002067360

ISBN 0 521 80956 8 hardback

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Introduction

The nature of value: differing paradigms

Perhaps the most often quoted definition of an economist is of someone who knows the price of everything and the value of nothing.[1] However, it is an awareness of the distinction between value and price which separates out the true economist from the glorified book-keepers and accountants who so often masquerade under such a title. Recent years have seen a growth of badge-engineering in which so-called new disciplines such as environmental or ecological economics have risen to prominence. However, whilst these are appealing titles, in essence they represent not a radical departure but rather a very welcome return to the basic principles and domain of economics – the analysis of true value.

It is one of these basic principles which underpins this study: namely the assumption that values can be measured by the preferences of individuals.[2] The interaction of preferences with the various services provided by a commodity generates a variety of values. Many economists have studied the nature of these values; however, a useful starting point is the concept of aggregate or total economic value (TEV) (Pearce and Turner, 1990; Turner, 1999; Fromm, 2000).

Figure 1.1 shows how TEV can be broken down into its constituent parts and illustrates these with reference to some of the values generated by the principal commodity under consideration in this study; woodland.

The bulk of economic analyses concentrate upon the instrumental or use values of a commodity. Most prominent amongst these are the direct use values generated by private and quasi-private goods (Bateman and Turner, 1993) which are often partly reflected by market prices, and those indirect use values associated with pure

[1] This is an appropriation of Oscar Wilde's definition of a cynic in *Lady Windermere's Fan* (Act III). However, given the perceived similarity between the two groups, it is easy to see how such a confusion may have arisen (with thanks to Olvar Bergland, Colin Price and others regarding this.)

[2] Speculations upon this issue and, in particular, about whether individuals have definite preferences are presented by Sugden (1999a).

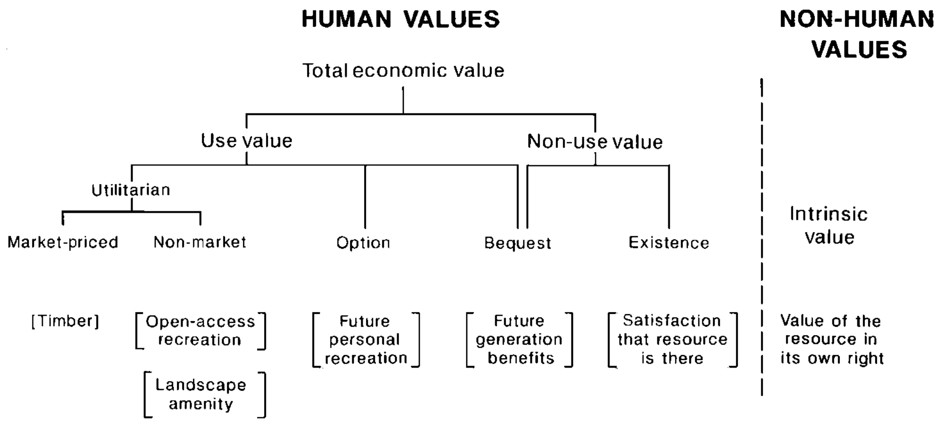


Figure 1.1. The total economic value of woodland. (*Source:* Adapted from Bateman, 1995.)

and quasi-public goods (*ibid*.) which generally have no market price description. A unifying characteristic of these values is that they are all generated via the present use of the commodity by the valuing individual. An extension of the temporal frame allows for the possibility of individuals valuing the option of future use (Weisbrod, 1964; Cicchetti and Freeman, 1971; Krutilla and Fisher, 1975; Kriström, 1990). Related to this is the notion of bequest value wherein the valuing individual gains utility from the provision of use or non-use values to present and/or future others. Pure non-use values are most commonly identified with the notion of valuing the continued existence of entities, such as certain species of flora and fauna or even whole ecosystems. As before, this is generally both an intra- and intergenerational value and because of the lack of an instrumental element has proved problematic to measure. Nevertheless, the theoretical case for the 'existence of existence value' is widely supported (e.g. Young, 1992).

Wider definitions of value have been argued for. An important issue concerns the extent of the 'moral reference class' (Turner *et al.*, 1994) for decision-making. One question here involves the treatment of other humans (both present elsewhere and future) while another is whether animal, plant and ecosystem interests should be placed on an equal footing with human preferences. The modern origins of such a view can be traced to O'Riordan (1976), Goodpaster (1978) and Watson (1979) who take the Kantian notion of universal laws of respect for other persons and extend this to apply to non-human others. Watson feels that those higher animals such as chimpanzees (which he argues are capable of reciprocal behaviour) should be accorded equal rights with humans. Hunt (in Perman *et al.*, 1996) and Rollston (1988) build upon the land ethic of Leopold (1949) to extend this definition of moral reference even further to include all extant entities, an approach which

Singer (1993) defines as the ‘deep ecology’ ethic. Such a paradigm argues that these entities possess an ‘intrinsic’ value separate from anthropocentric existence values. A further departure from conventional utilitarianism is proposed by Turner (1992, 1999) who argues that all the elements of TEV can be seen as secondary to a primary environmental quality value which is a necessary prerequisite for the generation of all subsequent values. Side-stepping the theoretical case for such philosophical extensions, a practical problem with these non-TEV values is that they are essentially beyond the scope of conventional, anthropocentric, preference-based economic valuation. If, as in this study, we constrain the moral reference class to present humans alone, TEV is the appropriate extent of value definition. However, this still leaves the problem of how such values should be measured.

One solution to the problem of valuation might be to abandon conventional neoclassical economic analysis in favour of modified or alternative appraisal and decision-making strategies. One such alternative is to base decisions upon expert judgement and restrict the role of economics to the identification of least cost methods for achieving stated aims (see, for example, Organisation for Economic Cooperation and Development, 1991). Such a cost-effectiveness approach may be optimal for a resource-rich risk-averse society faced with high risk, high uncertainty, irreversible problems such as the treatment of highly persistent pollutants (Opschoor and Pearce, 1991). Here a useful decision guide is provided by the precautionary principle advocated by ‘ecological economics’ (see, for example, Costanza and Daly, 1992; Toman, 1992; Turner *et al.*, 1995). However, in other, arguably more general, situations where the precautionary principle does not apply, a cost-effectiveness approach may entail avoidable and, in some cases, major net welfare losses compared to a solution based upon cost-benefit analysis (CBA). Such a position is adopted by those who argue for an ‘environmental economics’ paradigm (see, for example, Pearce *et al.*, 1989; Department of the Environment, 1991; Price, 1997a; Pearce, 1998; Griffin, 1998; Pearce and Barbier, 2000). Supporters of this view accept preference-based values as the basis of decision-making but argue for full assessment of TEV as opposed to the concentration upon market-based measures which appears to dominate much present practical decision-making.

This choice between ecological and environmental economics could be characterised as one between principle and pragmatism. The argument for an ecological economics approach is that nothing less will preserve the environmental integrity which is vital if the present, resource-exploitative, ‘cowboy economy’ (Boulding, 1966) is to attain a state of sustainable development. The environmental economic critique is that such a rigid approach fails to recognise the mechanisms through which present-day decision-making operates and thereby risks being ignored by those in power. In the absence of hindsight it is impossible to know which strategy is most likely to influence the presently unsustainable course of economic growth.

Our own position is that the two paradigms need not be in conflict and that a modified precautionary principle can be used to assess the most appropriate approach for any given decision situation. Furthermore, we see a role for public preferences within this process. In cases where expert assessment and/or informed public opinion identifies high potential risks or uncertainties from a given strategy or decision then a precautionary, ecological economics approach would appear justifiable. For situations where this is not the case then an environmental economics analysis seems likely to be optimal. From a sustainability perspective, both are significantly superior to simple market-based appraisals.

The theoretical and methodological basis of the study

We therefore need to select the appraisal paradigm which is most appropriate for the subject under analysis. This study examines the economic potential for conversion of land from conventional agriculture to multipurpose woodland in Wales. Two points are immediately important here. First, we are interested in the full range of economic values generated by such a change in land use. Second, following initial review (Bateman, 1991a,b, 1992), it has become apparent that large-scale unquantifiable risks or uncertainties are not a major factor in such an analysis. Given this, the adoption of a CBA paradigm appears defensible.

CBA is generally thought of as an appraisal of the worth of a project from a social perspective. That does not mean that CBA tells us about what is good or bad. Rather, it provides information, going beyond simple market-based assessments to a more complete analysis of value, which, if correctly employed, should improve decision-making (Adler and Posner, 1999). In our consideration of the social value of woodland we have attempted to be reasonably comprehensive although our main foci of interest are timber production, open-access informal recreation, and the value of carbon sequestration (i.e. global warming abatement). This is compared to the social value of agriculture. In both cases we consider items such as the differing subsidies currently paid by society to those who produce agricultural and forest products. However, while such a CBA assessment is of use in informing decision-makers and shaping optimal policy change, it cannot alone predict land-owners' and farmers' responses to that change unless the impacts upon farm incomes are also known. Consequently, the study also examines farm-gate incomes under present and future policy scenarios.

The ultimate objective of this study, therefore, is to provide a policy analysis tool. However, whilst the theoretical CBA framework of the research is conventional, the extent of application and the methodology employed is innovative and unique.

The role of geographical information systems

One distinctive feature of our research is the extensive use of geographical information systems (GIS) throughout our study. A GIS is commonly defined as 'a system for capturing, storing, checking, integrating, manipulating, analysing and displaying data which are spatially referenced to the earth' (Department of the Environment, 1987: p. 132). From an organisational perspective, a GIS typically involves computer hardware, software, data and operating personnel. The origins of what we now regard as a GIS can be found in the 1960s, but use has only become widespread in the past ten years (Burrough and McDonnell, 1998; Longley *et al.*, 1999, 2001). Technologies such as computer-aided design (CAD), image processing, database management systems and automated mapping have all contributed to the development of GIS, but the last of these represents a distinct advance in terms of the capacity to integrate data from different sources (e.g. relate point measures of timber yield to environmental characteristics of areas) and undertake a wide range of analytical operations. Examples of the types of questions that can be investigated using a GIS are given in Table 1.1.

The use of GIS in environmental economics is a relatively recent innovation[3] and in many ways their application could not be more overdue. The unrealistic assumptions, implicit or otherwise, made by economists in order to implement their analyses have often attracted critical comment, but GIS provide a means of avoiding many of the worst simplifications (Lovett and Bateman, 2001). For instance, studies using travel cost techniques to estimate the recreational value associated with open-access countryside locations have often assumed that all trips take place in straight lines between origins and destinations, and ignored much of the spatial heterogeneity within study areas (see discussions in Bateman *et al.*, 1996a, 1999a). With a GIS, travel costs can be calculated in a manner which is far more sensitive to the nature of the available road network and much greater account can be taken of spatial variations in the socio-economic characteristics of populations or the availability of substitute destinations (Brainard *et al.*, 1999). Another example where the application of GIS has already proved beneficial involves hedonic pricing techniques which aim to isolate the influence of environmental characteristics on property prices. In the past, efforts to examine factors such as views of parks, water features or industrial areas from properties have required considerable fieldwork (and involved appreciable subjectivity). The combination of high-resolution digital map databases and GIS, however, now makes it feasible to determine the composition of viewsheds from far larger numbers of properties in a more objective and cost-effective manner (Lake *et al.*, 1998, 2000a,b; Bateman *et al.*, 2001a).

[3] Among the few studies to date, not otherwise mentioned, to combine GIS and environmental monetary valuation are Eade and Moran (1996), Bhat and Bergstrom (1997), Geoghegan *et al.* (1997) and Powe *et al.* (1997).

Table 1.1. *Typical questions that a GIS can be used to answer*

Type of question	Example
Identification	What is at a particular location?
Location	Where does a certain type of feature occur?
Trend	Which features have changed over time?
Routing	What is the best way to travel between two points?
Pattern	Is there a spatial association between two types of feature?
What if	What will happen if a particular change takes place?

Source: Based on Rhind, 1990; Kraak and Ormeling, 1996.

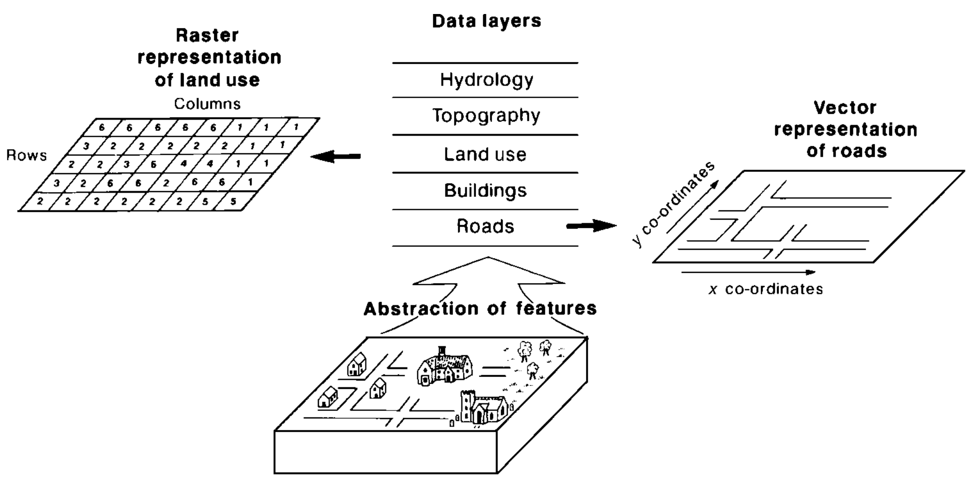


Figure 1.2. Representing real-world phenomena as raster or vector data layers. (*Source:* Based on Lovett, 2000.)

It needs to be emphasised that GIS are no universal panacea for improving data analysis. The quality of the results obtained depends on factors such as the accuracy of the input information and the appropriateness of the data structures used to store digital representations of real-world phenomena. Different types of features are most commonly held in a GIS as separate layers, usually in the form of either raster grids (where values are assigned to cells) or vector structures (where the positions of entities such as points, lines or areas are defined by sets of co-ordinates). Figure 1.2 illustrates these two main approaches. Other methods of data storage are possible (Laurini and Thompson, 1992), but the key principle is that data structures should be selected to minimise distortion when creating a digital representation of reality and maximise analytical or presentational options given the intended use of the data (Berry, 1993; Martin, 1996a; Burrough and McDonnell, 1998).

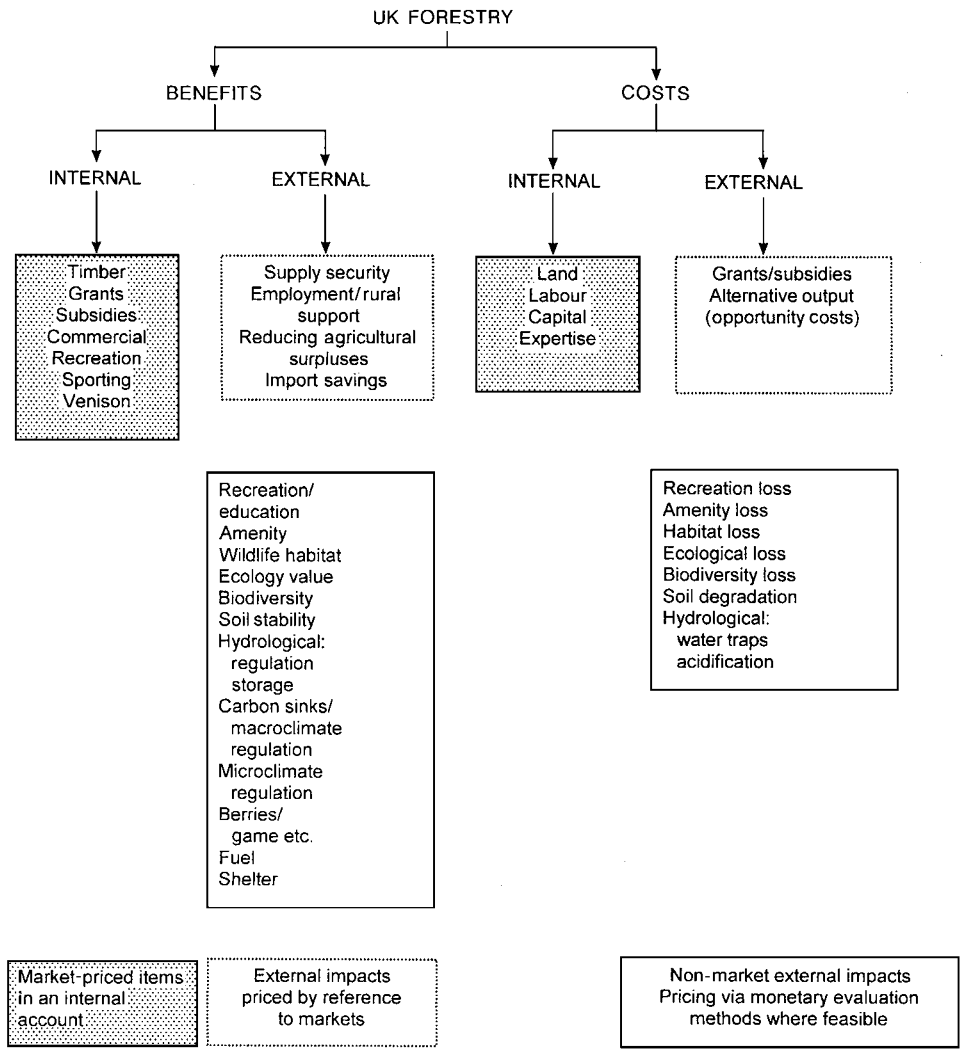
Notwithstanding the above caveats, by using GIS in this research we hoped to overcome many of the limitations in data handling and modelling which have restricted previous research. With such computing facilities we were able to combine environmental and other spatial data in the form of digital maps and satellite imagery with more conventional variables to enhance the stochastic economic models which are central to this study. As we demonstrate in the contexts of modelling timber yield, carbon sequestration, recreational demand and agricultural productivity, the ability to integrate diverse datasets substantially improves our capacity to understand and predict such variables. However, equally important is the scope for querying and visualising model output (e.g. in the form of maps), so permitting the decision-maker readily to comprehend the impact of alternative policy choices. It is this dual capability to improve modelling and display which we feel allows GIS significantly to enhance many aspects of economic analysis. (For a parallel example in the context of land use, see O'Callaghan, 1996.)

Costs and benefits of woodland: limitations of the study

Forestry has long struggled to compete financially with other land uses (Green, 1996) but has also been a consistent focus of attention regarding its non-market attributes (Hodge, 1995; Mather, 1998). Figure 1.3 illustrates the complexity of internal and external costs and benefits which are generated by woodland. In this diagram the internal costs and benefits are shown in shaded boxes. These items all have market prices from which shadow values, defining the value to society of these goods,[4] may be derived. Certain external items also have related market prices from which values may again be estimated; these are shown in the dotted line boxes of Figure 1.3. However, the remaining externalities do not have related market prices, thereby making valuation problematic; indeed such items are typically excluded from appraisals (Pearce, 1998; Hanley, 2001).

Our study sets out to provide a relatively comprehensive assessment of the values associated with the proposed conversion of agricultural land into woodland. However, we have to recognise certain limitations in the research. First, methods for the monetary evaluation of preferences for non-market goods and services are not uniformly developed for all types of value. In particular, methods for the evaluation of non-use benefits, such as existence values, have been the subject of sustained criticism during recent years (see Chapter 2). Our study reflects these reservations by concentrating upon use values. Second, time constraints and data availability

[4] Shadow values adjust market prices (which may be zero for unpriced goods) to provide estimates of the value to society of such goods. Typically this involves adjustments to allow for market failures, such as non-competitive markets, and transfer payments such as grants and subsidies which are funded by society. Chapter 8 provides an example of how shadow values may be derived from market prices.



Notes:

1. Here 'internal' refers to forest operator costs and benefits whether private woodland or Forestry Commission; 'external' refers to costs and benefits accruing directly to society.
2. Shadow pricing techniques must be applied to all values.
3. Not all the items listed may be valid (e.g. import substitution argument).

Figure 1.3. Costs and benefits of woodland. (*Source:* Bateman, 1992.)

problems mean that even our treatment of all use values is somewhat uneven. Third, we are only considering conversions from agricultural land to woodland and not to any other alternative use. Strictly speaking, this contravenes the principles of CBA, which state that the appraisal of opportunity costs should include the assessment of a wide range of feasible alternative resource uses (Pearce, 1986; Bateman *et al*., 1993a; Price, 2000; Hanley, 2001). A fourth issue is that of equity – and its root: ethics.

Ethical questions[5]

Ethics and economics have often been presented as strange bedfellows. Indeed, many proponents of the 'positive economics' which has dominated so much of twentieth-century economic analysis argue that the two concepts cannot be related 'in any form but mere juxtaposition' (Robbins, 1935: p. 148). However, this has not always been a widely held belief. Indeed the early great economists were explicitly concerned with morality and ethics.[6,7]

Two ethical positions which have had a major impact upon the development of economic thought are the libertarian and utilitarian schools of thought. The libertarian view, which may be traced from John Locke and Adam Smith to Robert Nozick (1974), emphasises respect for the rights of individuals. A fundamental concept here concerns the just acquisition of property. This has been interpreted as emphasising both the rights of ownership and also the requirement of appropriate payment or transfer in return for acquisition. However, libertarianism makes no prescriptions concerning the outcome of any trade or transfer. In particular, such a view would almost always condemn any redistributive policy, whether between present-day populations or to future populations (intra- and intergenerational transfers) unless they are freely entered into by all groups including donors.[8] This focus upon processes rather than outcomes differs from the utilitarian view (which derives from the writings of David Hume, Jeremy Bentham and, most notably, John Stuart Mill (1863)), which explicitly highlights the ethical consequences of actions. Classical utilitarianism judges actions according to whether they are 'good' for society, with 'good' being defined (by Mill) in terms of happiness or utility. Actions which promote utility are therefore good and should be judged by the amount of utility created. However, for utility to be cardinally measurable, individuals must be able to express it in terms of a numeric value. Furthermore, in order to assess the social utility of an action we have to assume that we can compare and add utilities across individuals.

These strong assumptions make classical utilitarianism of little use for the practical economic analysis of projects. The neoclassical utilitarianism (Kneese and Schulze, 1985) which underpins modern welfare economics involves rather weaker

[5] This discussion relies heavily on Perman *et al*. (1996), Kneese and Schulze (1985) and Pearce and Turner (1990). Relevant discussions are also presented in Beauchamp and Bowie (1988) and Sen (1987).

[6] Interestingly Adam Smith's post at the University of Glasgow was Professor of Moral Philosophy.

[7] Reviews of the work of Marx, Marshall, Pareto, Keynes and others are presented in Schumpeter (1952).

[8] This would conventionally rule out any governmental action towards the enforced provision of such transfers.

assumptions (Layard and Walters, 1978; Varian, 1987). In particular, a common assumption underpinning CBA is that the marginal utility of consumption is equal across all individuals. If this is so we can ignore distributive issues (which are vital under classical analysis) since any action which creates net benefits unambiguously raises social welfare. However, in reality, such an assumption seems unlikely to hold, prompting some users of CBA to consider explicitly the equity implications of their analyses (e.g. Squire and van der Tak, 1975). For many years such views were held by an inconspicuous minority within the profession of economics. However, since the 1960s, concerns regarding the effects of environmental degradation on present and future generations, together with the issue of North/South inequality, have meant that discussions regarding the ethical basis of economics have grown. These arguments over the need to consider equity as well as economic efficiency have recently coalesced within what has been termed the sustainable development (SD) debate (WCED, 1987; Pearce *et al*., 1990; Perman *et al*., 1999).

Both intra- and intergenerational equity issues are central to the SD debate which has, in essence, proposed an alternative to utilitarianism as a new ethical basis for economics. Pivotal to this has been the work of Page (1977) and, in particular, Rawls (1972). Rawls' theory of justice can be seen as a direct development of Kant's universal laws. Here the individual enjoys common liberties compatible with equal rights for others, while valid inequalities result only from personal qualities which are attainable by all (e.g. inequalities arising from diligent work or learning as opposed to those based upon sex or creed). This latter prescription has important consequences for equity, as Rawls argues that under such a system the optimal allocation of resources is one that is made behind a 'veil of ignorance' as to their intra- and intergenerational distribution. This can be seen as being in direct conflict with the individual maximisation principle of utilitarianism.[9] Such a contrast is perhaps most clearly demonstrated in the recent literature regarding sustainability. Turner and Pearce (1993) identify four alternative positions ranging from 'very weak' to 'very strong' sustainability. Each definition moves further from a conventional utilitarian towards a Rawlsian position on equity, steadily imposing more constraints upon resource use (most notably, natural capital).

The ethical position adopted in this study

There are a number of ethical positions which could be adopted in this research. Despite some considerable personal sympathy with the Rawlsian/'strong

[9] The economic implications of classical and neoclassical utilitarian and Rawlsian ethical positions can be expressed through consequent social welfare functions (SWF). Classical utilitarianism implies an additive SWF of the form: $W = \beta_1 U^A + \beta_2 U^B$ where $W =$ social welfare; $U^A, U^B =$ the total utility enjoyed by individuals A and B respectively; $\beta_1, \beta_2 =$ weights used to calculate W. Neoclassical utilitarianism relaxes the assumption of additivity such that $W = W(U^A, U^B)$. Finally, following Solow (1974a), the Rawlsian position can be expressed as the maxi-min function in which we maximise $W = \min\ (U^A, U^B)$. Note that Perman *et al*. (1996) suggest that Rawls may have strongly objected to the latter utilitarian reformulation of his work.

sustainability' view, our self-assessment is that this study is essentially neoclassically utilitarian in its ethical basis. The definition of values inherent in the TEV concept remains anthropocentric and is therefore consistent with the extended utilitarian view discussed by Perman *et al*. (1996, 1999). The most non-Rawlsian characteristic of this study is the absence of an explicit incorporation of any precautionary principle or equity constraint. It might be argued that the sensitivity analysis across various discount rates (discussed in Chapter 6), which we include in our CBA, effectively addresses the issue of intergenerational equity. However, as Hanley and Spash (1993) highlight, such an approach will not ensure equality of well-being across generations. Similarly, we do not include explicit considerations of distributional effects nor do we include any analysis which could be construed as compatible with a Rawlsian maxi-min criterion. Our approach is therefore conventional in terms of both theory and the ethical basis of such theory. It is only in the practical implementation of our analysis that we have attempted to improve upon convention.

This theoretical standpoint should not be taken as implying a wholesale rejection of the Rawlsian or 'strong sustainability' positions. Rather it is a pragmatic extension of accepted decision-analysis practice.

Selection of the case study and data sources

While the fundamental objective of this study is the comparison of woodland with agricultural values, a supplementary goal is to see how such differences vary across areas of differing environmental character. The country of Wales constitutes one of the most diverse areas of the UK with altitudes ranging from sea level to heights above those found in neighbouring England. While smaller than its neighbour,[10] the entirety of Wales represents a very much larger area than has been considered in virtually any CBA to date.[11] Furthermore, from the perspective of land use change, Wales provides a more interesting case study in that its diverse and relatively more adverse environment means that agricultural production is limited to sectors such as sheep-breeding which have been in long-term decline (see Chapter 9) and are therefore potentially more likely to be suitable for conversion to woodland (which has expanded throughout the past century; see Chapter 5). Wales is also interesting from an environmental point of view. While other areas

[10] The final CBA results presented in Chapter 9 are given in terms of 1 km square cells. The land area of Wales comprises some 20,563 such cells.

[11] Consideration was also given to extending the analysis to include England, which is considerably more populous than Wales. However, at the time our research commenced, agricultural census data for England were only available down to the parish level. Such resolution fails to identify individual farm locations thus rendering accurate production modelling infeasible. More recently the parish data have been interpolated to a grid cell basis that is available from the University of Edinburgh Data Library (see http://datalib.ed.ac.uk/EUDL/agriculture/). However, even these data do not report certain key profitability variables vital to our analysis of the opportunity costs of converting land from agriculture to woodland.

of the European Union (EU) have responded to falls in the real price of sheep by diversifying into other sectors, Welsh agriculture has seen an intensification of sheep-rearing with steadily increasing stocking densities (Fuller, 1996; Woodhouse, 2002). This in turn has raised concerns regarding overgrazing and its impacts upon wildlife (*ibid*.). A number of economic and environmental factors therefore single out Wales as a particularly suitable subject for our case study.

Data sources

Our research draws upon data from a number of sources. All data were provided free or for a reasonable handling charge. We are very grateful to a number of people and organisations for this co-operation without which the research could not have been undertaken (see Acknowledgements to this volume). Detailed descriptions of the various datasets are provided in subsequent chapters, but a brief summary is given here.

Data on farm-level agricultural activities, costs and revenues were obtained from the Farm Business Survey in Wales (FBSW). We are indebted to the enlightened attitude of the FBSW which, by being prepared to enter into a confidentiality agreement whereby no farm-level results were reported, allowed us to use grid-referenced farm data which could be linked to local environmental characteristics, so facilitating a substantial improvement in the ability to model agricultural production and its value.

Environmental data were provided in the form of the LandIS database, kindly loaned by the Soil Survey and Land Research Centre (SSLRC), Cranfield. This is the premier repository of land information data for England and Wales. When used in conjunction with the FBSW data, LandIS provided the highest-quality combination of information possible for modelling agriculture in the study area.

Our other principal data source was the Forestry Commission's (FC) Sub-Compartment Database (SCDB). This is the most extensive and comprehensive source of woodland data in the UK and is again geographically referenced to a high degree of accuracy, permitting integration with the environmental data contained in the LandIS database.

A number of other sources were employed to provide specific variables. These included Bartholomew's 1:250,000 digital map database made available to UK universities under a CHEST agreement, 1991 Census data purchased for academic research use by ESRC/JISC, details of windiness provided by the Forestry Commission and digital maps of Environmentally Sensitive Area boundaries supplied by the Ministry of Agriculture, Fisheries and Food. The project also involved surveys and interviews which are described later in this book, the structure of which we now consider.

Context and structure of the book

The majority of the research presented in this book was undertaken for a Ph.D. thesis (Bateman, 1996).[12] A number of journal articles discussing individual aspects of the research have since been published and are referenced in appropriate chapters, but this book brings these elements together allowing the integrated results to be considered in detail.

Many of the data used refer to the early 1990s and, given, in particular, the constantly changing context of agriculture and to a lesser extent forestry, we are wary of asserting that all findings are directly transferable to the present day. However, it remains our strong contention that the methodology adopted is still relevant and capable of wider application. At appropriate points in the text we have sought to provide some updating of the economic and policy context and to comment on the applicability of the substantive findings in the light of this.

As discussed above, the book considers the application of environmental economics using GIS through a case study concerning woodland, agriculture and a CBA comparison of land use change between the two. We begin with a consideration of the recreation value of woodland. This is subdivided into an appraisal of methods for the monetary evaluation of woodland recreation (Chapter 2), a review of previous valuation studies and presentation of our own studies (Chapter 3) and GIS-based analysis transferring results from these various evaluations to the case study area through predictions of the latent demand for visits (Chapter 4). The focus of attention then shifts to timber and a further evaluation model is constructed (Chapter 5) and applied to newly estimated timber yield models (Chapter 6). Our analysis of woodland values is concluded by extending the definition of values to include the net benefits of carbon sequestration (i.e. counteracting the greenhouse effect of global warming) provided by forests (Chapter 7).

We then turn to consider the opportunity cost of converting land to woodland, which in the case study area of Wales involves losses of agricultural production. Models of both the farm-gate and social values of such production are presented for the dominant farming types of the area (Chapter 8).

The preceding analyses are finally synthesised through cost-benefit analyses of potential conversions of land from agricultural to woodland use (Chapter 9).[13] Both market and social-perspective assessments are presented and the results clearly demonstrate the sensitivity of findings to whether analyses are restricted to consideration of market prices alone or extended to include non-market values. Further

[12] Further details of this thesis can be obtained by navigating from the CSERGE website at http://www.uea.ac.uk/env/cserge/ or by going directly to Ian Bateman's personal home page at http://www.uea.ac.uk/∼e089/.

[13] The analysis also indicates, by default, whether conversions from existing woodland to new agriculture are justified, although our results indicate that this is rarely the case.

sensitivity is found regarding which agricultural sector is considered for conversion, the choice of discount rate, choice of woodland tree species and many other policy variables. Perhaps most markedly, our GIS-based methodology highlights the spatial dimension of CBA decisions, showing that the same policy decisions yield social and market gains or losses depending upon the location chosen for policy application (Chapter 9). This analysis therefore identifies a number of interesting results from which policy implications and conclusions are drawn and presented (Chapter 10) along with an assessment of the methodology adopted in the research and consideration of the scope for further extensions, certain of which are ongoing.