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Economic analysis for ecosystem assessments: Application for the UK National Ecosystem Assessment (NEA)

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**Economic analysis for ecosystem assessments:
Application for the UK National Ecosystem
Assessment (NEA)**

by

Ian Bateman

CSERGE Working Paper EDM 09-12

ECONOMIC ANALYSIS FOR ECOSYSTEM ASSESSMENTS: APPLICATION FOR THE UK NATIONAL ECOSYSTEM ASSESSMENT (NEA)

Ian J. Bateman¹

23rd October 2009

Abstract

The paper considers methodological issues pertinent to the economic assessment of ecosystem services. It is primarily written for a natural science audience however it also proposes a methodology which is intended to be of interest to economists charged with undertaking valuation work for ecosystem service assessments.

The first part of the report introduces the concepts underpinning the economic approach towards the assessment and valuation of ecosystem services. The second part considers the particular issues arising for the economic analysis of findings from the UK National Ecosystem Assessment (NEA)

Annexes to the paper use a case study approach to illustrate particular issues. The first concerns potential conversions from agriculture into multi-purpose woodland and illustrates the quantification and valuation of land use change. The application of geographical information system (GIS) routines allows spatial complexity to be incorporated within the analysis. Key concepts are illustrated such as making allowance for subsidies, the marginal value concept, and the valuation of non-market externalities (such as carbon storage of open-access recreation). The case study also shows that, if issues such as spatial variation and externalities are ignored then sole reliance upon market prices can lead to perverse outcomes which are actually to the detriment of society. This spatial focus is extended in a second annex to consider issues arising in the aggregation of values. A third annex reproduces a short questionnaire sent to natural scientists working on the NEA intended to help identify the goods which will be the focus of the economic analysis.

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1. Basic concepts

Prices and values

Perhaps the source of most confusion in practical decision making are two common place terms which most people use interchangeably: 'value' and 'price'². That they are not in fact equivalent is actually very easy to demonstrate. Consider that most basis of all necessities, water. This is the staff of life without which existence is impossible. Yet the price we pay for water in our household bills is actually very modest. It is clear to see that 'value' and 'price' are not necessarily the same thing. In fact price is simply that portion of underlying value which is realised within the market place. Now in many cases price may be a perfectly acceptable approximation to value, particularly for goods produced in competitive markets³ and where there is not large scale intervention by governments or other authorities⁴. Indeed even when these latter distortion do arise economists can often adjust for their influence to yield what is known as the 'shadow value' of the goods concerned. However, as the water example shows, market price can in some cases be a poor approximation of value, indeed this divergence can often be substantial and is a characteristic of many of the goods produced by the natural environment (note that, in an attempt to enhance the clarity of this discussion, I will refer to the physical processes and outputs of the natural environment as its 'services' but when referring to their economic value I term these as 'goods').

Why then do prices diverge from values? One fundamental reason is due to property rights. Some services can readily be owned. For example, individuals can purchase woodlands and use private property laws to exclude others from chopping down their trees. The owner can now sell those trees at a price (the determination of which we will consider shortly). However, other clearly valuable services are much less amenable to private ownership. For example, that same woodland will store carbon from the atmosphere and so help contribute to ameliorating the impacts of adverse climate change. However, at present this is considered as a public good; the benefits disperse across the globe and the woodland owner cannot exclude others from enjoying those benefits and (currently) receives no compensation for that good (although note that this example also illustrates the fact that we can construct new markets for what were previously public goods and generate private benefits for producers; e.g. the European Union Emission Trading System (EU ETS) could potentially be extended to generate benefits for those who store carbon).

Even when goods are protected by private property rights, their price may only be a poor indicator of their underlying value. This is reflected in one of the oldest conundrums of economics; Adam Smith's Water and Diamonds Paradox. Writing in the 18th century, Smith puzzled that diamonds, which had no practical purpose other than ostentation, commanded much higher prices than water which clearly was, *in-extremis*, of infinite value. The reason for this is of course differences in demand and supply for each good. While our demand for water is of course huge, so is its supply – it literally does fall from the skies! This interaction of demand and supply leads to the prevailing low price of water⁵. Diamonds on the other hand only occur in a few areas of the world and even there they have to be mined from deep

² Another common and related confusion concerns the terms 'accountant' and 'economist'. Accountants are interested in market prices, whereas the true economist should be interested in values.

³ Typically, the less competitive a market the more any individual producer can exerting pressure upon price.

⁴ Interventions such as government subsidies or taxation can strongly distort prices away from their competitive market levels.

⁵ Of course where either demand or supply changes so does price. Consider, for example, the long standing drought in Australia and how this affects water prices.

underground using costly techniques⁶. The supply of diamonds is consequently small relative to their demand, resulting in high prices.

As we can see from the water example, demand and supply can interact in ways which are highly beneficial to consumers, providing goods at prices which are below the value consumers have for those goods. This excess between price and value is known as the 'consumer surplus'⁷. Of course decision makers should be interested in the value which different goods provide rather than their price. Indeed this constitutes the fundamental difference between accountants and economists. While the former are interested in price, the latter are (or at least should be) interested in value. Indeed it is not an overstatement to say that economists are ultimately interested in happiness; although with this being the dismal science they usually prefer to talk about 'utility'⁸.

The fundamental problem facing any economic analysis is one of measurement; how do we measure the value or utility provided by any given good? Most commentators would argue that we cannot define direct and interpersonally comparable units of pure utility⁹. The economists solution is to use a surrogate measure which is highly compatible with the decision making process, transparent and amenable to subsequent adjustment if we wish to allow for different circumstances across individuals. That measure is to assess the amount that individual's are prepared to pay for changes in the provision of goods. Note immediately that we are relating value to willingness to pay (WTP)^{10,11} rather than what actually has to be paid. A simple example serves to illustrate the importance of this difference. Consider the value of walking in a woodland. This generates benefits such as exercise, appreciation of nature, perhaps entertainment of one's children, inner calm, etc. Yet if this were a publicly owned woodland the amount paid to enter such a wood is likely to be zero. Clearly here price paid is a highly misleading indicator of value.

Arguably there is no perfect ways in which to estimate the value of any good. However, several decades of research have resulted in the development of a variety of valuation methods including the following:

⁶ Note that costs are simply reflecting the prices of the factors (e.g. land, labour, capital, etc.) used in producing goods.

⁷ Note that those efficient producers who faces costs which are below the prices they receive also enjoy what is known as a 'producers surplus' being related to the difference between costs and prices. The same good may generate both producer and consumer surplus.

⁸ Although note that this reticence is declining; see Kahneman (2000) and Layard (2005) for examples.

⁹ The classic work on this issue is that of Jeremy Bentham (1789). However, there are some interesting countervailing views. See for example, Binmore (2005).

¹⁰ Typically the WTP measure is taken as referring to the amount an individual is prepared to pay for some gain in the provision of a good (technically this is the 'compensating gain' in goods which just balances the lows of income). However, three other money measures of utility change are available. The 'equivalent loss' measures the amount of income individuals would pay to avoid some loss of a good. Conversely we can think of an individual's willingness to accept (WTA) money compensation to endure some loss of a good (otherwise known as the 'compensating loss'). Finally we can also measure the 'equivalent gain' in income which just offsets not receiving some gain in goods. The seminal text here is Hicks (1943) although the four measures are empirically compared in Bateman et al., (1997, 2000a).

¹¹ A common objection to WTP measures is that they are inherently unfair in that the extent to which an individual can express their willingness to pay must be constrained by ability to pay (i.e. income). One could argue that this is no different to the situation for market priced goods (my ability to buy a luxury car is limited by my income). However, setting this aside, the distributional aspect of the WTP measure can to some significant degree be addressed by reweighting the value estimates to allow for this problem (i.e. giving greater emphasis to the willingness to pay of poorer groups).

- Adjusted market prices¹²: For goods which are traded in markets and have prices we can estimate WTP by examining the reaction of demand to observed variations in prices. Adjustments need to be made for distortions arising from imperfect (non-competitive) markets, policy interventions (e.g. taxes and subsidies), etc. This allows the analyst to estimate consumer surplus and hence values. For example, one can estimate part of the value of improved water quality by examining the increased value of commercial fishing catches.
- Productivity methods¹³: Ecosystem services often provide the factors of production required to produce marketed goods. Production functions relating inputs to the output of goods can be estimated and the contribution of individual services assessed. Continuing the water quality improvement example, one could also estimate the value generated by greater agricultural productivity, or the decreased costs of providing clean drinking water.
- Revealed preference methods¹⁴: Many goods which capture environmental services can only be enjoyed through money purchases. For example, individuals may pay extra for homes in quiet neighbourhoods or incur substantial costs to visit areas of natural beauty. By relating behaviour to the characteristics of those goods one can observe the money-environment trade-off and so reveal the values held by individuals for the environmental good.
- Stated preference methods¹⁵: The most direct of all approaches is to ask individuals to state their willingness to pay for some change in the provision of an environmental good.

In practice the costs of conducting novel valuation research across the multitude of potential decision situations often means that analysts are forced to rely upon value transfer methods¹⁶ which transfer existing benefit estimates from studies already completed for another location or issue.

In addition to the various valuation methods described above, many studies adopt simpler 'pricing methods' such as avoided damage approaches which examine the costs of avoiding damages due to lost or at-risk services (e.g. the cost of building sea walls to replace lost

¹² For an example concerning the valuation of non-timber forest products see Godoy et al., (1993). The use of market prices within a green accounting approach to assessing ecosystem services is discussed by Cairns (2002). Arrow et al., (2007; see also Dasgupta and Mäler, 2000 and Dasgupta, 2009) develop a "Comprehensive Wealth" approach which adjusts national income to allow for ecological depletion while Mäler et al., (2008) adopt a production function approach.

¹³ For examples see Ellis and Fisher (1987) and Barbier and Sathirathai (2001).

¹⁴ For further discussion of revealed preference methods see Champ et al., (2003) and Bockstael and McConnell (2006). Two methods dominate the field; the travel cost method (for valuing recreational use of sites) and hedonic pricing. Problems of such methods include the difficulty of imputing costs for travel time and visits (Randall, 1994) and the complexity of estimating utility measures from hedonic data (Day et al., 2007).

¹⁵ For further discussion of stated preference methods see Bateman et al., (2002) and Kanninen (2006). Two techniques dominate the field; the contingent valuation method and choice experiments. One of the problems of such methods is that respondents are liable to answer valuation questions even if they have little understanding of the good concerned. This results in the phenomena of 'preference construction' (Ariely, et al., 2003; Kahneman, et al., 1982; Slovic, 1995) where respondents effectively 'make up' answers to questions they do not understand or rely upon the framing of the valuation questions to infer the 'correct' answer. A number of tests have been developed for identifying such constructed preferences (Arrow, et al., 1993; Bateman, et al., 2008) and it is important that any stated preference study conduct and satisfy such tests before any reliance is placed upon their findings.

¹⁶ Also known as 'benefit transfer' methods. For further discussion see Navrud and Ready (2007).

coastal marshes). These are not true valuation methods as they are not based upon WTP. The common error arising from using such methods is to assume that the costs of avoiding damage somehow relate to the true value of the service under assessment (e.g. that sea wall construction costs are proxy for the value of coastal marshes or valuing improved water quality by measuring the cost of controlling effluent emissions¹⁷). This is clearly erroneous.

Economic values as human constructs

Economic valuation methods seek to assess all of the diverse values which individuals have for the range of goods they enjoy. These can include values related to the use of those goods and non-use values related to their bequest for others or just the simple pleasure obtained from the continued existence of some entity (for example the value one might hold for the pristine existence of Antarctica, even though the person expressing that value might not ever expect or even want to visit the place). Note that all of these values relate to human preferences, so the existence value of blue whales is that accorded by humans. Philosophical objections might argue that many entities also have an 'intrinsic' value quite separate from human appreciation, e.g. the value of the blue whale for itself. Economic theory does not dispute this (indeed it is mute on the subject) but it does note that we can never measure such intrinsic values and therefore cannot compare them with those goods which we can value. If humans value the existence of a species then that value should be included in economic analyses. However, if humans do not value that existence it will not be included in economic analysis¹⁸.

There is a fundamental issue here; note that the economic definition of value is entirely anthropocentric with value being seen as a uniquely human construct. Economics is posited upon an essentially anthropocentric notion where present humans determine value (Pearce and Turner, 1990; Fromm, 2000) which can then be adequately measured (Turner, 1999, 2007). Some reject this approach arguing that valuation raises intractable problems (Aldred, 2002). Typically such critics favour a rights based approach, some arguing for equal treatment between present and future humans (Rawls, 1971) or that higher-animals such as chimpanzees (Watson, 1979) should be accorded equal rights with humans. Some go further by arguing for the rights of extant entities (Leopold, 1949; Rollston, 1988). Side-stepping the theoretical case for such philosophical extensions, a practical problem with these approaches is that they go beyond the scope of conventional, preference-based decision making and valuation; we simply cannot quantify the preferences of non-humans. Furthermore, while the need to impose constraints upon development to conserve and restore the ecological integrity of the environment is clear, the logical consequence of a rights based approach is to stultify all economic change; an option which is simply unworkable given the need to rise to the challenge of human induced global environmental change.

One of the consequences of values being essentially human constructs is that they are a reflection of individual's preferences – and these are not necessarily correlated to any objective, scientific measures. So, for example, most of those living in the UK appear to prefer rivers which are dominated by one form of life (fish) rather than another (algae). There is no clear reason for this other than pure preference.

¹⁷ This and certain other examples in this section are taken from ecosystemvaluation.org which provides a useful overview of the methods under discussion.

¹⁸ Indeed, to the author's knowledge, there is no way in which intrinsic values can be catered for other than via a rights based approach. This emphasises the rights of different species (indeed different entities) to exist. A problem with such approaches is that they ultimately stifle any move from the status quo as such rights are inalienable and non-tradable. This is very clearly removed from anything resembling the real world situation facing the policy community where decisions have to be made. Such stances are therefore ultimately of little use in such contexts.

To date we have implicitly assumed that, while individuals may have little knowledge of many of the primary and interim services provided by ecosystems, they are aware of their own preferences for the goods they value. While personal preferences may indeed be well known for commonly consumed, high experience goods, this assumption becomes more dubious when we consider low experience and novel goods. This may be a minor problem if values can be inferred through examining patterns of consumption, but it becomes a more substantial problem when considering non-use values. Typically these can only be assessed through stated preference methods and here a lack of robust preferences may undermine the validity of any derived values. For example, individuals may know that they want tigers to be conserved (and indeed this 'good' might be used to subsume the complex ecosystem services which generate the habitats of such species). However, it is highly likely that they have no prior conception of their WTP for tiger conservation. A problem here is that any such values (say those elicited via stated preference methods) are likely to be highly malleable. Studies have shown that in such situations stated preference survey respondents may 'construct preferences' (Slovic, 1995) during the course of the valuation interview, often using the framing of valuation questions as heuristic cues to the 'correct' response (Green et al., 1998). More fundamentally, in such situations respondents may not even have preferences for the good in question and so may instead refer to some wider or alternative group of goods (e.g. all conservation activities)¹⁹.

There is no ideal solution to the problem of incomplete preferences. One possibility is to examine policy decisions or social preferences for evidence of underlying if unquantified preferences. If such evidence exists then the provision of such goods as conservation could be set as requirements of and constraints upon economic activity. The economic task then is to identify the most cost-effective route for providing such goods. Arguably this should have some requirement for consideration of excessive cost, although in the absence of reliable values this has to remain a subjective assessment. The adoption of safe minimum standards (SMS)²⁰ and similar precautionary approaches would seem appropriate in such circumstances.

The use of SMS may also be appropriate as a response to the risk of irreversible losses (or, more accurately, losses which are economically irreversible given the disproportionate costs they would incur). We return to this problem in our subsequent consideration of temporal issues.

The valuation of final goods rather than interim services and the avoidance of double counting

A further important consequence of preference based values is that individuals do not hold preferences for services that they do not know about, and typically won't hold values for many other services they do not fully understand. This is an understandable cause of frustration for many natural scientists who are concerned that economic valuations will ignore important services. A knee-jerk reaction to this dilemma is to either suggest that individuals should somehow be informed about these services and educated into their overt appreciation, or that values should be determined by informed 'experts', or that economic analysis should be abandoned. All of these strategies are to be avoided. The 'educated preference' or expert judgement approaches result in evaluations which are not commensurate with any of the other values to be included elsewhere in the economic analysis. We do not reject the shadow value of food as coming from an ill-educated mass

¹⁹ Here the seminal text is Kahneman and Knetsch (1992). For a recent application testing the robustness of stated preferences to the tiger conservation example see Bateman et al., (forthcoming).

²⁰ See, for example, Crowards (1998), Turner et al., (1998) and Fisher et al., (2008).

who place too much emphasis on eating high-fat, low-nutrition meals; why then should we massage other estimates to yield 'correct' values? Abandoning economic analysis might seem attractive at first – but the simple fact is that any decision has economic consequences in that it adjusts the balance of resources available and so impinges upon the opportunities open to society; there are no 'non-economic' options.

This does not mean that there is no solution to this problem, in fact in essence (if not necessarily empirically) the solution is simple. Economic valuation analyses should be applied not to the host of elemental and interim services which constitute the ecosystem, but rather to the final goods that they produce²¹. To illustrate this consider the issues of microbial soil processes, an ecosystem service about which most individuals would have very little understanding. Attempting to directly derive economic values for such poorly comprehended services is to be avoided, but this does not mean that they have no value as they play a vital role in plant production (Derouard, et al., 1997). Plant growth results in a variety of further services which in turn yields goods for which individuals do hold economic values, which can then be assessed. One of these goods is food production which of course is readily amenable to valuation. This example further serves to show that the final goods which are the object of valuation are not purely composed of ecosystem services but also include other inputs such as manufactured capital (machinery etc.), human capital (labour, knowledge, etc.) and so on²².

An important principle for ecosystem service assessments is therefore to ensure that economic analyses focus upon the goods which are produced by those services rather than the multiple interlocking services themselves. Such a strategy avoids the related problem of double counting. Given the complexity of ecosystem relations, multiple services contribute to the production of an good with some services providing the necessary basis for others and so on up the production process until final goods are produced²³. So, considering the previous example, food is produced through the interactions of soil microbial services, natural fertilisation processes, pollination services and multiple other services. Attempts to value each of these individually (aside from being plagued by the problems of low comprehension mentioned previously) are likely to lead to over-estimates of the overall value if these interim service values are added together. Furthermore such disaggregation ignores the fact that each service often forms a vital link in a chain which together produces goods; the removal of any such link does not just lower value by some part but rather it results in the complete loss of that good²⁴. A much safer strategy is to isolate the final goods which are produced whether wholly or in part by these services and then value those goods.

Total and marginal values

Perhaps surprisingly, economics makes no claim to be able to assess the total value of certain goods, particularly many of those associated with the non-market, life-support

²¹ For further discussion of this view see Daily (1997), Balmford et al., (2008) and Fisher and Turner (2008). Note that this position differs somewhat from that of Boyd and Banzhaf (2007) and stands in contrast to MA (2005) and Wallace (2007).

²² See discussions in Fisher and Turner (2008).

²³ Fisher and Turner (2008) stress that ecosystem services do not have to be utilized directly but can be intermediate processes underpinning successive services.

²⁴ Arguably one could try and disaggregate values for final goods, allocating this value to the constituent services. However, this process ignores the links between services which are vital to the production of goods. As an analogy (with thanks to Brendan Fisher), consider my car, a Nissan Micra, and its constituent parts. Now the Micra is a very unassuming car, devoid of status to impress, such that the only good it provides is that of transportation. A number of interim services are required for this transportation good to be delivered. There are the power services of the engine, the rotational services of the wheels and the support services of the frame. If any one of these services is not in place then the final good is not delivered and the car loses all of its transportation value, only retaining a residual value as scrap.

services provided by the environment. This can be readily proven by reconsideration of the water example. We can assess individuals' willingness to pay for a considerable range of changes in the provision of water. However, there must be an infinite value loss associated with the removal of all water. Therefore attempts to assess the total value of vital life support systems such as the world ecosystem go beyond economics and into the realms of speculation²⁵.

Economics then does not attempt to value the whole of any vital service. However, as this is not the normal sphere of decision making this is not a problem. Instead economic analysis confines itself to the valuation of changes in provision rather than the complete removal of provision. A key concept here is the value of an additional unit of provision; this is referred to as the marginal unit and hence its value is known as the marginal willingness to pay (MWTP). This useful concept allows us to assess the value of many typical (i.e. non-extreme) changes in provision²⁶.

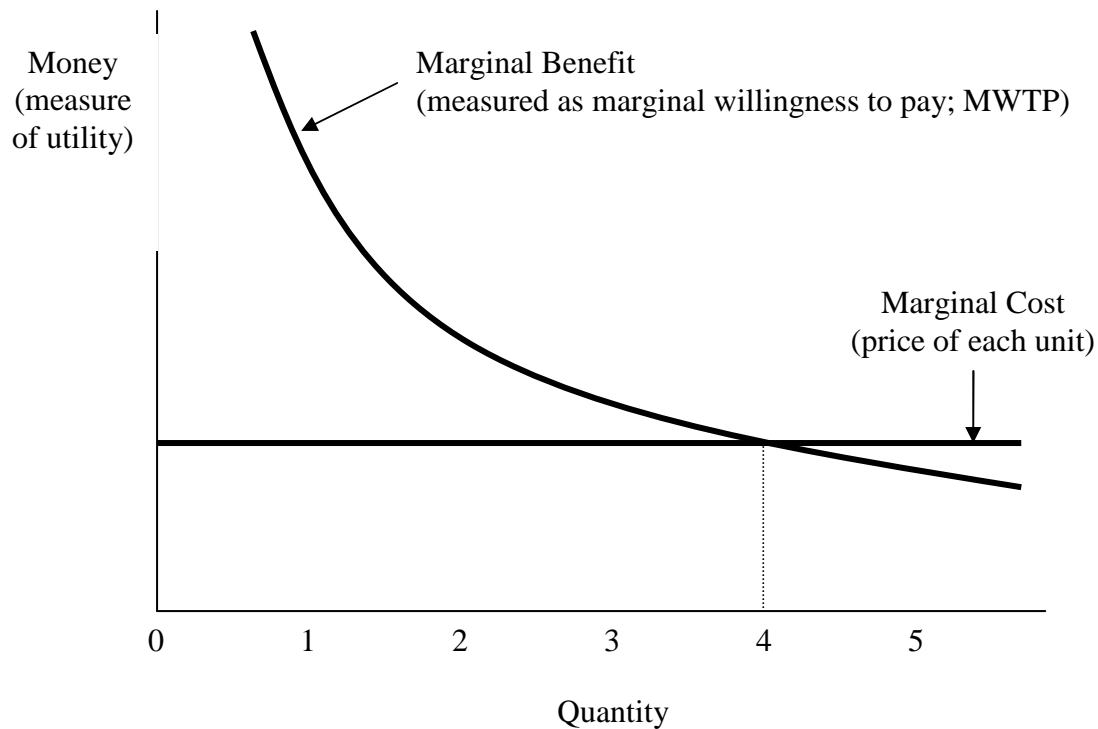
Economics shows that most decisions are made using marginal rather than total values. Taking a simple domestic example using a marketed good; consider the decision about how many smoke detectors a household should purchase. These devices offer fire warnings which might save the life of those who live in the house. Given this, many households clearly feel that these are vital life-support services (analogous to claims regarding many ecosystem services) and own at least one detector. Given the relatively modest (if not insignificant) cost of such detectors and the dreadful consequences of a fire why then do we not see households with detectors in every room of the house? The answer is because, in considering each additional detector, individuals weight the cost of the detector (its market price) against the benefits it will provide (its utility; measured by the MWTP for that additional detector). The marginal benefits of having an initial detector far outweigh the marginal cost and a purchase is made. However, when a second purchase is made a crucial and fundamentally important difference is observed: while the marginal cost of each detector remains constant, the marginal benefit of the second detector is lower than that of the first. Why? Because the risk reduction provided by the first detector (which is assessed against the baseline given by the risk of having no detectors) is greater than the risk reduction afforded by the second (which is assessed against a baseline of already having one detector). Now it may well be that the marginal benefit (measured by MWTP) of the second detector is larger than its marginal cost and that second detector is purchased. However, this diminishment of the utility of a marginal detector contains as further purchases are considered. Lets suppose that a third detector delivers greater marginal benefits than costs and is purchased but by the time a fourth detector is considered the marginal reduction in risk it provides gives a benefit which has a MWTP only as big as its marginal cost. We say that the individual is indifferent about purchasing this fourth detector; whether they buy the detector or save their money will make no net difference to their overall utility. Now consider a fifth detector; here the marginal benefit (and hence MWTP) further declines to be lower than its marginal cost, so the individual definitely will not purchase this detector. At most this individual buys four detectors (although they would be as happy just buying three). Even through the fifth detector does reduce household risks it is not purchased. Therefore we see

²⁵ While the study by Costanza et al., (1997) constituted an important contribution in terms of raising awareness of ecosystem services as an economic good, nevertheless the study has been the subject of strong criticism in terms of its attempt to estimate the total value of the ecosystem (which by definition must be infinite given its vital role in sustaining all life) rather than assessing the value of some feasible change in the provision of those services. The Costanza et al., value of total ecosystem services has therefore been described as 'an underestimate of infinity'.

²⁶ An important issue here concerns the definition of the baseline from which a provision change is quantified and subsequently valued. Typically, the baseline would be the current status quo level of provision. However, in a world of rapid environmental change it is often true that the level of provision of a good will change even if there is no policy intervention (e.g. ongoing development may be leading to progressively higher levels of pollution). Such changes must be incorporated within any valuation analysis

why households do not have smoke detectors on every surface. Figure 1 provides a graphical representation of this analysis.

Figure 1: Diminishing marginal utility (reflected in diminishing MWTP)



With the marginal value of each smoke detector now known we can now calculate the total value of some change in the provision of these goods. This is achieved by simply summing the marginal values between the relevant provision points. More generally we can state that the calculation of the aggregate value of some provision change for a good requires three vital pieces of information:

- (i) Clear understanding of the change in provision of the good under consideration (i.e. the number of extra units being provided);
- (ii) A robust and reliable estimate of the marginal (i.e. per unit) willingness to pay (MWTP); and
- (iii) Knowledge of how (ii) might alter as (i) changes.

In the above example this is a relatively easy calculation if we want to find the total value of moving from say one smoke detector to four; it is simply the integral of the MWTP curve between these limits. Note also that we can work out the total cost for this change (the integral of the marginal cost curve between these limits). Subtracting the former from the latter gives us the total consumer surplus of this change (i.e. that surplus value which the individual does not have to pay for). However, the calculation becomes much more difficult if we try to estimate the total value of all smoke detectors, including the first. Notice that as we try and reduce the number of detectors to zero, so the marginal benefit curve tends toward

some unmeasured but very high number. This is because the household considers the value of detecting fires to be very high and feels that with no detectors they run an unacceptable risk of catastrophic events. It might be that the MWTP of this first detector is bounded only by the available income of the household²⁷ (a situation where willingness to pay becomes a poor estimate of value). Consequently, economic analyses should avoid attempts to calculate such total values and focus instead upon valuing the feasible changes which are the realm of real world decision making.

Two general lessons come from the above analysis. First, decisions are made by considered marginal values (both benefits and costs) rather than total values. Indeed total values are generally of little help to the decision process. Second, marginal utility tends to diminish as quantity increases. While the above analysis considered (for simplicity) a private good, its straightforward to demonstrate that the same effect can hold for public goods. Consider the provision of open-access parks for recreation purposes. To make things simple lets consider a situation where the relevant authorities are considering providing a number of such parks and also that in the area under review there are presently no such parks. It's easy to imagine that the benefits of the first park could be very substantial and that the taxpayers of the area might have a high MWTP easily outstripping the marginal cost of its provision. So the first park is provided and the authorities consider the case for a second park. The key result here is that, with the first park provided (and the baseline shifted from zero to one) so we would not be surprised to find that MWTP for the second (marginal) park was lower than that for the first. The remainder of the analysis proceeds in a manner akin to that shown in Figure 1 and the optimal number of parks is determined. We do not end up with infinite numbers of parks²⁸ – because that is not what people want; at some point marginal benefits fall below marginal costs.

A further issue is that the marginal value of providing a given park depends on where it occurs in the sequence of provision. While the physical characteristics of each park may be identical, their value is highly contextual. This makes the valuation of a good substantially more complex than its physical quantification. It also means that the transferability of value assessments is highly challenging and indeed only recently have valuation studies begun to consider the real world context of different sites when conducting such transfers²⁹.

In principle then the marginal benefit of any good varies according to how much of that good has already been provided. However, the rate at which marginal benefits (and hence MWTP) declines with increased provision varies greatly between goods. The park example above shows a case where the rate of decline is rapid. A much slower rate of decline is to be expected if we consider a good such as carbon sequestration. The storage of one tonne of carbon will have such an insignificant impact upon the value of storing a subsequent tonne of carbon that we can in practice ignore this effect and assume a constant marginal value for each tonne. Here then valuation becomes more straightforward. Only if the baseline level of storage massively increased, or carbon emissions radically reduced, or an alternative form of storage was introduced (a substitution effect) would we see significant falls in the marginal benefits of further sequestration.

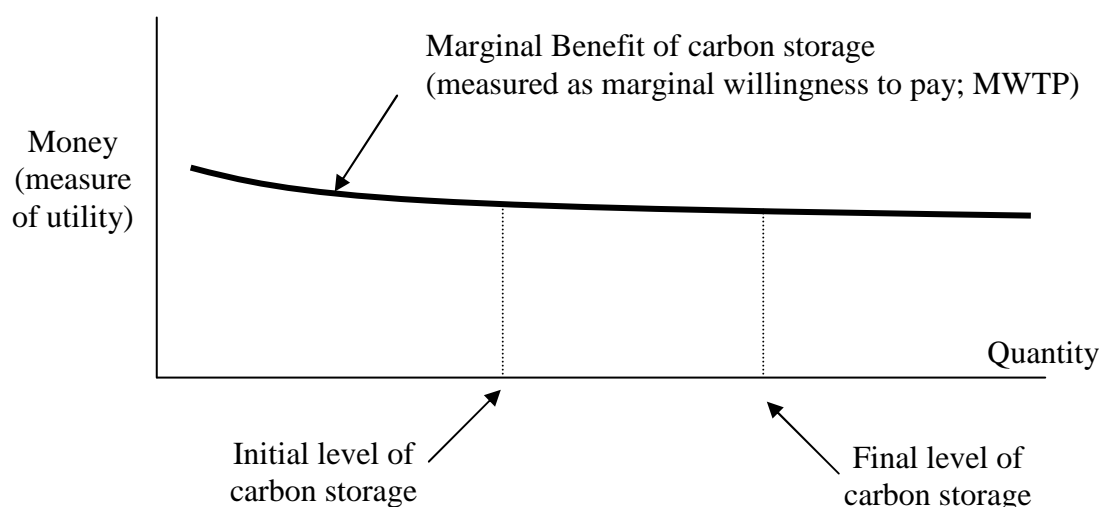
²⁷ One might wonder then why a producer does not offer their smoke detectors at some incredibly high price. Indeed this might happen if there was only one producer. However, competitive markets allow other manufacturers to move into such production. The competition between such producers avoids the higher prices that can arise under monopoly situations and as prices are driven down so individuals begin to capture consumer surplus and expand their purchases of such goods.

²⁸ Similarly we do not end up with parks of infinite size as the marginal benefit of an additional hectare of parkland declines as the total area increases. This means that assessments which use constant per hectare values are likely to be flawed. To date there is relatively little work on how values do change with size although for an exception see Brouwer et al., (1999).

²⁹ See for example Bateman et al., (2009a).

In effect, while for many goods we would expect to eventually observe diminishing marginal benefits for further provision (or increasing marginal benefits where there are losses of a good), a key issue is the range over which any provision change occurs. This range may span only a relatively flat portion of the MWTP curve (as per feasible changes in UK carbon sequestration). Here variation in the size of marginal benefits might be fairly minor and indeed might even be ignored; Figure 2 illustrates such a case using the example of carbon. However, for other goods or for other changes in provision the situation may involve rapidly varying marginal values. In such cases this variation cannot be ignored.

Figure 2: Effectively constant MWTP: The case of carbon sequestration



All of the above discussion has been based upon scenarios of gains where the provision of a good is increasing. However, we can use the same marginal analysis to assess the value of losses incurred as provision decreases. The key result here is that as losses occur the marginal value of a good need not remain constant and if anything is likely to increase³⁰. Returning to Figure 1 we can see the losses which would occur if, for some reason, the availability of smoke alarms was restricted such that individuals' could only purchase one per household. The loss value would again be calculated by integrating under the MWTP curve but this time between four detectors down to just one (i.e. the integral gives a negative sum, indicating a loss)³¹. Such a scenario does not seem very likely to occur for private goods such as smoke alarms where consumption is essentially just price constrained. However,

³⁰ See Balmford et al., (2002) for discussion of this point in relation to losses of ecosystem services.

³¹ This example makes the implicit assumption that individuals react to gains and losses in a symmetrical manner. This might seem trivial but there is actually considerable evidence to suggest that individuals do not treat unit gains and unit losses as simply the negative of each other. Seminal work by Kahneman and Tversky (1979) and Tversky and Kahneman (1991), together with empirical verification by Bateman et al., (1997), indicates that individuals tend to over-value losses relative to gains. Although work by List (2003) and Bateman et al., (2009b) suggests that increasing experience and better provision of information tends to reduce gains-loss asymmetry the latter also indicates that some residual effect is retained. This causes a considerable dilemma to decision makers as unit gains might not be traded off against unit losses, a major problem given that almost all major investments involve winners and losers. The extent to which such asymmetry is primarily an ex-ante problem associated with contemplation of losses as opposed to a genuine and lasting disparity robust in ex-post situations is a further complication. Given the present lack of quantification of such effects across the myriad of different decision contexts arising in the real world it may be better to treat this as a cautionary issue for qualitative rather than quantitative treatment.

such scenarios are much more common for public goods such as the open-access parks also discussed above. Here consumption is typically quantity constrained and of course there are plenty of areas where it seems reasonable to suppose that park provision does not match up with peoples' preferences. Nevertheless, the methodology remains the same with losses being calculated by integrating the MWTP curve from the current provision level down to some new changed level.

Before concluding this part of the discussion, it is worthwhile noting that the emphasis upon the valuation of ranges of changes within which marginal values may change but do not become entirely non-marginal contrasts with the approach adopted by Costanza et al., (1997) who attempt to provide estimates of the total value of ecosystem services. This approach has been criticised on a number of grounds including the observation that very few policy decisions do relate to total losses of any ecosystem service. The method has however been defended as analogous to National Income Accounting (NIA). However, in valuing ecosystem services and their resultant benefits we are trying to gain an insight into their contribution to human welfare. NIA is not designed to be a measure of welfare³², but rather an accounting exercise³³, such that it gives us a measure of economic activity as a compilation of goods. NIA approaches typically use the current price as an indicator of a certain good's quality. However, multiplying the quantity of items by their current per unit price does not give a reliable indicator of the welfare generated by that good as it excludes consumer surplus and does not reflect the change in the marginal benefit of goods as the quantity consumed varies. This is particularly true when we consider the loss of ecosystem services. As the quantity available decreases so we would expect the marginal value of each unit to rise; using the current market price ignores this³⁴.

Aside from illustrating the principles of marginal valuation, the examples given in this section also serve to highlight the vital importance of accurately quantifying both the present level of provision and any change in that provision level. Given the problems of calculating total economic values down to zero provision levels, analyses need to focus upon changes

³² As an aside William Nordhaus and James Tobin came up with the Measure for Economic Welfare in 1972 saying that National Accounts like GDP metric worked well as a measure of welfare, but by the late 1960's ceased being a good measure as they added 'bads' with 'goods' and ignore much of which is important but unaccounted for like unpaid childcare (see Nordhaus and Tobin, 1972).

³³ Note however that a cost-based perspective can tell us about what it costs society if we continue to degrade the natural capital stock at historical rates. Bartelmus (2009) argues that extended national accounts should not attempt measuring economic welfare. Rather, they could and should assess the environmental sustainability of economic activity as the cost of natural capital consumption.

³⁴ Consider, for example, the tragedy of Easter Island recently highlighted by Diamond (2005). Here the native population died due to their own progressive destruction of the islands forests. Taking the value of a tree when the forest is still relatively untouched and applying this to the entire forest stock would clearly massively underestimate the value of the entire forest by ignoring the progressive increase in the marginal value of remaining trees as the forest stock dwindles. National income accounting ignores this increase in marginal values as the stock falls.

between ex-ante and ex-post provision levels. Quantification of provision change can of itself be a major undertaking and examples of such analyses are provided in Annex 1 to this paper. A major element of this analysis is the incorporation of spatial variation in both provision change and valuations, to which we now turn.

Spatial issues

Spatial issues are fundamental to the economic assessment of many goods and in particular those associated with the environment. Location can determine the change in provision under analysis. Annex 1 to this paper considers a land use change example which shows that the provision changes generated by converting agricultural land into woodland vary substantially by location. Some areas generate much better tree growth than others, carbon storage can vary dramatically according to local soil type, etc.

Spatial relationships also affect the value of any given change in provision. Returning to the open-access park example, placing such a park in close proximity to population centres will generate a much higher value than if that park is created in some remote and inaccessible area³⁵. Empirical studies have quantified the 'distance decay' in values which occurs over space for some goods although to date such examples only cover a small minority of goods³⁶.

We have already seen from our discussions of the MWTP curve that each additional unit of as good reduces the marginal value of any subsequent units. So, the value of the marginal park is reduced by the presence of others which act as partial substitutes. The effectiveness of one park as a substitute for another depends crucially upon their spatial proximity to each other. Distance decay suggests that the closer parks are to each other the greater will be their substitution effect. Furthermore, other goods might also act as substitutes to lower marginal values. For example, imagine that the area is near to the coast and has lots of pleasant beaches for open-access recreation. However, again it is spatial relationships which will determine the strength of this substitution effect. Further complexity arises in the form of the quality of each of these resources, with higher quality sites exerting greater substitution effect.

Another practical problem in allowing for substitution effects is that it is not always obvious which goods should be considered in such analyses. So, while beaches might provide good substitutes for parks, what about heathland, field boundaries, private gardens, etc? Only empirical analysis will indicate what is relevant for inclusion in such studies.

A related issue concerns the spatial extent of any analysis. If an analysis is conducted on an inappropriate scale then the likelihood of error is substantial. For example, if individuals are prepared to travel up to 20 miles to visit a park when there are no substitutes available then restricting the analysis to a smaller area than this is likely to underestimate the value of that park. A related and common problem is the extrapolation of values pertaining to the population close to a site across a wider area without adjusting for the decay in those values that occurs as distance increases. Annex 2 presents a case study showing that distance decay relationships have to be incorporated into such analyses with allowance being made for the location of the site relative to the spatial distribution of population.

³⁵ Balmford et al., (2002) make this point with respect to ecosystem services. As an example they note that high local values of services such as tourism may not be maintained if extrapolated over larger areas and would generate major errors if used in worldwide estimates.

³⁶ See, for example, the study of river recreation goods by Bateman et al., (2006a). However, even this is highly limited, considering just one site and failing to explicitly incorporate the spatial relationship with substitute sites. Substitution effects are more thoroughly examined by Jones et al., (2002) but this only considers the number of recreational visits and not their value.

Temporal issues

While values vary spatially, they also change temporally. In part this is due to changing preferences over time. For example, consider the case of UK wetlands which were once more commonly and derisively termed 'bogs' and considered to be waste land to be improved by drainage. Now such wetlands are highly valued for their ability to provide superb wildlife habitat. To some degree this can be explained by the dwindling supply of such natural resources³⁷ (it is noticeable that in countries where such resources are still common they are often less prized). However, increasing real incomes and leisure time together with better transportation and a growing appreciation of the services of such areas all play a part in the transformation of such values. This causes considerable difficulty for economic analyses as it is difficult to assess changes in future preferences.

The fact that economic assessments have to be conducted from some point in time (typically the present day) introduces further temporal complexity. Individuals prefer benefits to be provided sooner rather than later (and the opposite for costs). This seemingly innocuous facet of preferences leads to the problem of discounting; that the present day value of future benefits (and costs) falls the further into the future those values occur. Determining the nature and rate of this decline is important as it can radically alter present day assessments of the value of different options. What is clear is that the economist should not adopt the discount preferences of the individual but rather use a social discount function (Pearce et al., 2003). This reflects the longevity of society and the greater weight placed upon delayed benefits and costs relative to the preferences of individuals. That said the choice of discount function can have massive impacts upon the economic assessment of long term concerns such as ecosystem services and sensitivity analyses of the impact of different discounting strategies are advisable.

Perhaps the most complex and least well understood of all temporal issues are those of interactions, tipping points and irreversibilities. So far we have only considered the value of a good in terms of the intended services it provides. However, the production of a good can also have wider impacts. These include interactions with other goods which generate 'externalities'. These may vary from benefits such as the relief of unemployment or costs such as pollution of water courses. It is one of the central tenets of economic cost-benefit analysis that all of the costs and benefits of any investment should be assessed (including the opportunity costs of forgoing alternative investments of the resources involved). While clearly this is a good principle to follow, in reality there is a highly imperfect understanding of the interactions which arise between highly complex systems such as those which abound in the natural environment. Such interactions might be highly non-linear and characterised by tipping-points where environments that appear stable or to react linearly as changes occur, suddenly flip into radically different states once some threshold is breached (see, for example, Dasgupta and Mäler, 2004). This difficulty is made more complex by the possibility that certain such changes may be economically irreversible, i.e. such reversal could only be achieved by incurring disproportionate cost (Kahn and O'Neil, 1999). For example, the loss of tropical forests may be extremely difficult and hence unfeasibly costly to reverse if exposed soils are rapidly eroded and degraded. Concerns about irreversibility would tend to increase the usefulness of SMS and precautionary approaches (Fisher et al., 2008) to the management of ecosystems over time (working in the opposite direction to discounting effects).

A final consideration which is both temporal and general concerns information gaps. One of the major problems facing an economic analysis of ecosystem service assessments is the paucity of data and studies available on values associated with ecosystems. Despite four

³⁷ The seminal work in this area is by Krutilla and Fisher (1975).

decades of growth in the valuation of non-market goods such as those provided by the natural environment, the available stock of knowledge remains inadequate to the complexity of the demands upon it. This reflects an inherent aversion to investment in knowledge as well as a focus upon disciplines rather than interdisciplinary natural and social science. This results in a degree of uncertainty regarding the value of different provision options which is far from satisfactory. The biggest problem facing any empirical economic analysis is the lack of information regarding the multiple issues raised in the preceding discussions. That said, ongoing research is attempting to address this knowledge gap. In the following section we consider the particular issues likely to arise when these principles are applied within one particular assessment; the UK National Ecosystem Assessment (NEA). Following this, Annex 1 to this paper reports an example of a partial economic assessment of one possible scenario for change, in this case concerning land use.

2. Application of economic analysis to the UK National Ecosystem Assessment (NEA)

Principles

The concepts discussed in the preceding section form a set of principles for applying economic analyses to ecosystem assessments. We can summarise these as follows:

- We distinguish between the physical processes and outputs of the natural environment, which we term ‘services’ and the objects which generate economic values, which we refer to as ‘goods’.
- Economic analysis is concerned with values rather than prices, the two differing due to consumer surplus:
 - Values are approximated by measures such as individuals’ willingness to pay (WTP) for the good in question.
 - Under certain conditions (notably private goods traded in competitive markets) prices may be an acceptable approximation of values.
 - In other cases (notably public goods which are not traded in markets) price may be absent or a poor guide to value.
 - In the latter cases a variety of methodologies exist for estimating values.
 - Some goods (notably low experience non-use goods) may not be amenable to valuation due to the absence of robust preferences. Cost-effective solutions for delivering safe minimum standards (SMS) may be appropriate here.
- Economic values are human constructs:
 - They include the values individuals’ obtain from using goods (use value)
 - They also include values for goods which individuals do not use but wish to preserve (non-use values)
 - They exclude ‘intrinsic’ values arguably possessed by non-human entities.

- Economic analysis pertains to the final goods valued by individuals, not to the various services which are required for the production of those goods.
 - Attempts to value services rather than final goods are liable to result in double counting
- Economic analysis focuses upon marginal values
 - The marginal willingness to pay (MWTP) for a marginal unit of a good diminishes as the quantity consumed increases. Therefore MWTP rises as we consider progressive losses of a good.
 - MWTP will eventually become infinite for vital goods. Therefore attempts to assess the total value of such goods (driving their availability to zero) are to be avoided.
 - Economic analysis should focus upon assessing the value of feasible (non-total) changes in the provision of goods. This requires:
 - (iv) Clear understanding of the change in provision of the good under consideration (i.e. the number of extra units being provided);
 - (v) A robust and reliable estimate of the marginal (i.e. per unit) willingness to pay (MWTP); and
 - (vi) Knowledge of how (ii) might alter as (i) changes.
- Spatial issues are fundamental to the economic assessment of many goods
 - Variations in the natural environment characteristics of areas play a part in determining the quantity of ecosystem services and hence goods which can be provided by that area.
 - The use values generated by spatially confined goods tend to decay with distance. Therefore the location of those goods relative to populations will alter their value.
 - The location of substitutes relative to spatially confined goods will alter their value.
 - Spatial effects therefore have to be allowed for in assessing the value of spatially confined goods.
- Values also vary temporally.
 - Preferences may change over time.
 -
 - The socioeconomic and other characteristics of populations may alter resulting in changes in WTP.
 - The present day value of benefits and costs are progressively discounted the further into the future they occur.

- As time passes so the probability increases of interactions, tipping points and irreversibilities between and within ecosystem services. The uncertainties induced by such effects increase the desirability of SMS and precautionary approaches to the management of ecosystems.
- Information gaps.
 - One of the major problems facing an economic analysis of ecosystem service assessments is the paucity of data and studies available on values associated with ecosystems.

Application to the NEA

A number of aspects of the design of the NEA make it particularly suitable for the application of economic analysis.

The NEA focuses upon changes to ecosystem service values over a specified period (from the end of WWII to 2060). Although processes such as climate change and habitat conversion mean that there will be substantial changes to ecosystem services during this period, in general we will not be dealing with the total losses of those services (an exception to this is certain biodiversity services which we discuss further subsequently). This avoids the problem of non-marginal changes and the estimation of total values. This in turn means that economic analysis is generally appropriate to such an assessment.

The economic analysis of the NEA should follow the principles set out in the previous section. We distinguish between the physical processes and outputs of the natural environment, which we term 'services' and the objects which generate economic values, which we refer to as 'goods'. These include both use value and non-use value goods.

Some consideration is required regarding the identification of goods within the NEA. The natural science elements of the NEA draw upon the methodology developed by the Millennium Ecosystem Assessment (MA, 2005). This identified four categories of ecosystem services, as follows:

- (1) Provisioning services (cited examples include: Food; Fibre and fuel; Natural medicines and pharmaceuticals; Fresh water; etc.)
- (2) Regulating services (cited examples include: Water regulation; Erosion regulation; Water purification and waste treatment; Pest regulation; Pollination; Climate regulation; etc.)
- (3) Cultural services (cited examples include: Spiritual and religious values; Natural beauty and intellectual stimulation; Aesthetic values; Recreation and tourism; etc.)
- (4) Supporting services / Ecosystem Processes (cited examples include: Primary production such as plant growth for provisioning and regulating services; Nutrient cycling; etc.)

While this categorisation has proved very useful for natural science ecosystem assessments it does not make the necessary distinction between services and goods (and hence has the potential for double counting if all services were valued). In commenting on the MA, Mäler et al., (2008) note that it requires some modification for economic analysis and seek to identify those final goods which directly affect human wellbeing and separate them from 'intermediary services' (p.9502). Similar arguments are put forward by Fisher and Turner (2008) and a detailed analysis of the potential for moving from the MA framework to a set of

final goods suitable for economic analysis is given by Balmford et al., (2008). While the latter provides a useful starting point, in preparing for the economic analysis of the NEA all of the Contributing Lead Authors (CLAs) of the natural science assessment have been asked to fill in a simple questionnaire concerning their conception of the final goods pertaining to their area of assessment. The questionnaire and accompanying letter are reproduced in Annex 3 of this paper.

Once goods have been identified the economic analysis seeks to value these. For each good this requires:

- (a) Clear understanding of the change in provision of the good under consideration (i.e. the number of extra units being provided or lost);
- (b) A robust and reliable estimate of the marginal (i.e. per unit) value of the good; and
- (c) Knowledge of how (ii) might alter as (i) changes.

Although prices may be taken as indications of marginal values for some goods (e.g. private goods traded in competitive markets), elsewhere findings from valuation studies will be used. A variety of valuation methodologies will be applied to obtain these values.

Spatial variation will be explicitly incorporated into analyses (see Annex 1 for examples of how spatial issues can be assessed). This analysis will seek to incorporate how variation in natural environment characteristics will affect changes in the provision of goods. The impact of population distribution and the availability of substitutes will also be considered. Aggregation will be undertaken to three spatial scales: All UK; National; Sub-national (e.g. Regional District Area). Annex 2 considers issues of spatial aggregation.

The long time period considered in the NEA lends itself to the incorporation of temporal issues. The analysis will consider temporal variation in preferences and populations characteristics and will undertake a considered sensitivity analysis of discounting impacts.

A number of issues remain for debate. The incorporation of interactions, tipping points and irreversibilities between and within ecosystem services and their impact on goods and economic values needs to be tackled. Similarly the uncertainties induced by such effects mean that consideration needs to be given to precautionary and SMS approaches. Incorporation within economic analysis requires further consideration. Such approaches, possibly accompanied by cost-effectiveness analysis, may also be required to address problems arising from limitations to robust valuation, for example, regarding certain biodiversity related goods. Finally we recognise that one of the major problems facing an economic analysis of ecosystem service assessments is the paucity of data and studies available on values associated with ecosystems and the uncertainties surrounding threshold effects. These are key issues which will need to be directly addressed as part of the economic analysis of the NEA.

Annex 1.

Economic analysis of a major change in ecosystems: the case of land use change.

A1.1. Introduction

The issues of changes in provision relative to the status quo, internal and external costs and benefits, and the consequent generation of value gains and losses are relevant to all goods but they are of particular pertinence to the analysis of land use change. Land use is determined by a wide range of drivers including shifts in national and world markets, policy initiatives and environmental factors such as climate change. The highly diverse pattern of existing land uses and variation in the physical environment characteristics of that land mean that these drivers will have highly variable impacts in different areas (e.g. planting trees will have very different consequences in terms of timber yield across the country and the value of the resulting woodlands in terms of recreation benefits will vary substantially according to how accessible forests are and how many substitute woodlands already exist). This means that we have to bring spatial issues into our analysis. Furthermore, many impacts do not occur immediately (e.g. the slow speed at which carbon balances can shift in response to land use change). Therefore our analysis also has to have a time dimension. This is important because individuals are not indifferent to the timing of when costs and benefits are incurred and tend to progressively reduce (or 'discount') values which occur further and further into the future when assessing their equivalent present day value.

Bringing all of these factors together means that the challenge for economics is to undertake spatial-temporal cost-benefit analyses of the value of land use change. In this Annex we illustrate the key concepts discussed in Section 1 of this paper by exploring a single case study in depth. This features an analysis of the multiple internal and external costs and benefits generated by considering land use change from agriculture into multi-purpose woodland. The case study considers both spatial and temporal effects to identify and estimate net benefits (gains minus losses) in each area of a large case study area; the entirety of Wales. The heterogeneous nature of this area means that such land use change generates very different values in different areas at different times, thus illustrating the vital importance of considering spatial and temporal issues. We start by addressing the most fundamental question of any policy: What is the change in provision that it will generate?

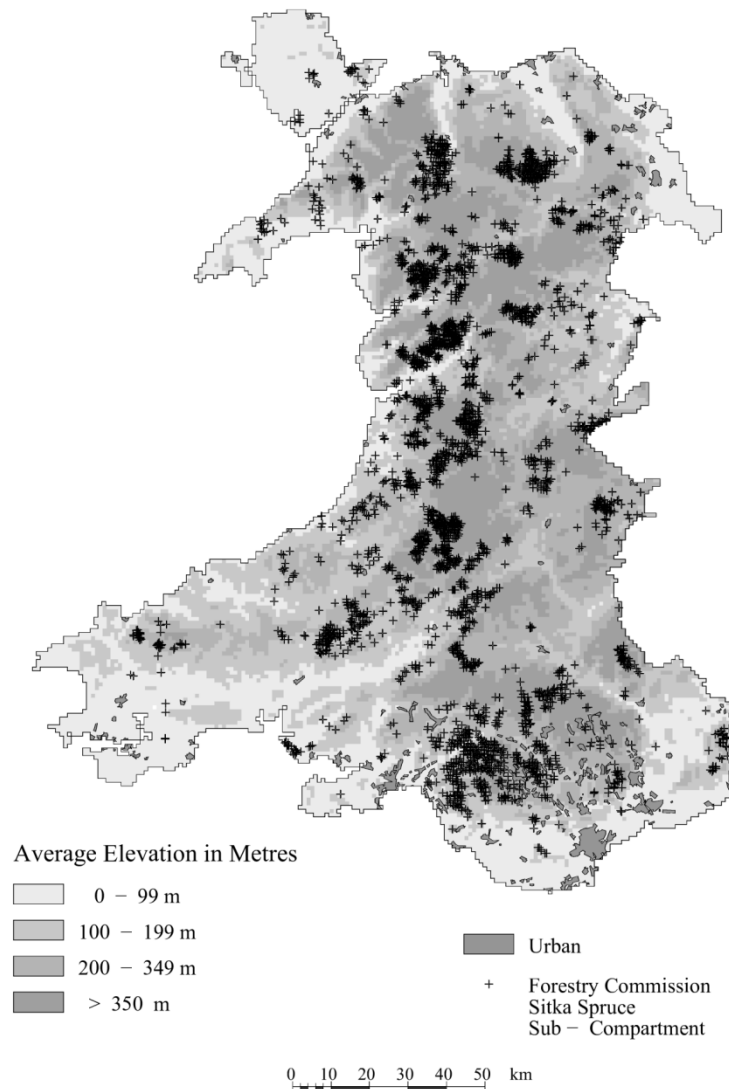
A1.2. Bringing spatial issues into estimation of the change in provision induced by land use change

One of the initial challenges for practical cost-benefit analysis is to estimate in quantity terms the changes in provision that are to be valued. It is clearly unreasonable to expect valuation studies to derive robust values for a good when the quantity change in provision (and/or the quality change) is unknown.

In the case of land use change the analyst clearly cannot treat all areas as being equal. Thinking of our case study regarding the potential for net benefits arising from land use change from agriculture into woodlands, an obvious provision change which we need to consider is how well trees will grow in different areas. In order to address this we start by examining the available data³⁸ regarding tree growth. Bateman et al., (2003) examine several thousand records of tree growth collected by the UK Forestry Commission from their forestry 'sub-compartments' located all over the study area, as shown in Figure A1.1.

³⁸ Data availability is generally good in the UK across a number of dimensions. Clearly this is not true of all situations and data limitations will be a constraint upon any analysis.

Figure A1.1: Location of Forestry Commission sub-compartments for one species (Sitka spruce) in Wales (superimposed upon elevation)



Source: Bateman et al., (2003)

Examination of Figure A1.1 shows that, while we have observations scattered across a wide variety of areas, there are many places where we do not know how trees grow. We therefore cannot rely solely upon the raw data to answer our question regarding the best places for land use change from agriculture into forestry. Such problems are common, in fact the same issue arises with respect to farming; while we know about agricultural output in many areas, by no means do we have records for all areas.

We therefore need a means of predicting the provision change induced by land use change (here tree growth) in all areas from data which covers just a subset of those areas. Given that we know that tree growth can change abruptly over relatively small areas (due to soil type changes, altitude, etc) then we cannot simply assume that every area is like every other area. The solution then is to build a model of tree growth which incorporates all of the factors which

influence that growth. Statistical techniques allow us to build such models. Here we relate each sub-compartment tree growth record to the physical environment, management and other characteristics of that sub-compartment. These characteristics include many variables (such as soil type, elevation, rainfall, etc.) for which we have records for all areas of the country. Therefore by showing how these factors determine tree growth in the sub-compartments we can then use those relationships to predict tree growth in all areas of the country. Table A1.1 details a statistical model, estimated using regression techniques, which predicts the growth rate of a particular tree species as a function of the characteristics of each area.

Table A1.1: Best fitting regression model predicting Sitka spruce yield (m³/ha/year)³⁹

Predictor	Coefficient	t-ratio
Constant	16.710	47.92
Elevation	-0.009	-22.31
Rainfall	-0.002	-15.65
Shelter	0.024	3.20
Good soil	0.805	10.00
Poor soil	-4.883	-5.05
Area of forest	0.004	10.43
Year planted	0.050	10.31
1st Rotation	-1.928	-17.64
Mixed crop	-0.308	-4.02
Parkland	0.948	10.10
Ancient forest	0.927	3.00
Uncleared forest	2.641	11.61
Low inputs	-0.085	-10.49
Lower inputs	-0.434	-4.59
Lowest inputs	-5.142	-6.73

Source: Bateman et al., (2003)

Models such as those given in Table A1.1 tell us a lot about how the characteristics of each sub-compartment determine the rate at which trees will grow in it. The first column set outs the determinants ('predictors') of timber yield. The last column tells us how significant each of those predictors are in determining yield. These are t-ratios and any value outside the range from +1.96 to -1.96 is considered to be statistically significant (and the further outside that range the more significant a factor is). All of the variables listed here are very highly significant in determining timber yield. The value in the middle column describes the relationship between each variable and the timber yield. The 'Constant' tells us what the timber yield would be if all of the other variables had a value of zero (here it says that yield would be 16.71m³/ha/year).

³⁹ The model reported in Table A1.1 is based upon tree growth records from 4307 sub-compartments across the study area. The model fitted the data well, yielding a higher degree of fit than recorded in previous tree growth studies (R-sq(adj.) = 42.8%).

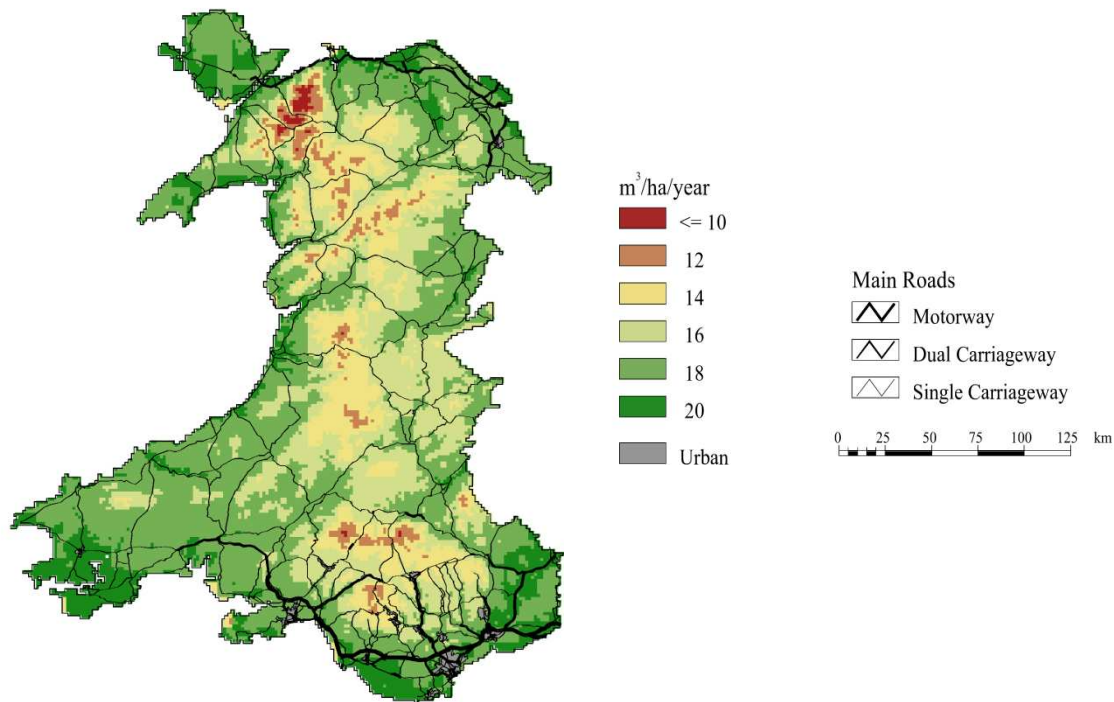
Of course it is implausible that all the other variables would have a value of zero and their coefficients tells us how yield changes as each one of those variables increases by one unit. So the 'Elevation' variable shows us that if the woodland was one unit (here 1m above sea level) higher then the timber yield would decline by $0.009\text{m}^3/\text{ha}/\text{year}$. This is of course a tiny change, but this result helps answer more useful questions such as the impact of planting a forest 100m higher above sea level, which is now a non-trivial loss of $0.9\text{m}^3/\text{ha}/\text{year}$. Similarly the 'Rainfall' variable shows that as the amount of rain in an area increases by one unit (here 1mm) so timber yield falls⁴⁰ by $0.002\text{m}^3/\text{ha}/\text{year}$; a substantial effect when one considers that rainfall across Wales varies from 1000mm to 3000 mm annually (Met Office, 2009) thus inducing a variation in yield of $4\text{m}^3/\text{ha}/\text{year}$ from this factor alone. The remainder of the model is similarly readily interpretable, identifying those factors that either increase or decrease timber yield and in each case quantifying that relationship⁴¹.

Notice that the model is composed of two types of variables, those linked to the physical environment and those which describe the effects of management on trees (as an example of the latter the Mixed Crop variable shows us that this species tends to grow at a slightly lower rate when mixed with other species rather than being grown in a monoculture; illustrating a familiar landscape diversity versus timber output dilemma for the forester). We can set these latter management factors in line with any desired policy (e.g. preferring mixed species stands over monocultures). Turning to the physical environment variables, the UK enjoys a wealth of data with information on all these factors being held at a very high degree of resolution for the entire country. We can now use this information to predict timber yield for every location across the country and so estimate the physical provision change which would be induced by an afforestation project at any given location. Results from such an analysis are given in Figure A1.2, which indicates the physical provision change of an afforestation project and shows where the highest timber response would be achieved.

Figure A1.2: Estimating a physical change in provision: Predicting the timber yield produced by planting trees in different locations across Wales

⁴⁰ International readers might be surprised that the model shows tree growth decreasing as rainfall rises. However, Wales is one of the wettest areas of a high rainfall country such that even higher rainfall is associated with particularly adverse conditions for tree growth. Nevertheless, if we were to build a model of tree growth for a much drier country then we would expect the coefficient on rainfall to become positively related to tree growth. This example underlines the need for great caution when extrapolating statistical models 'out of sample' (i.e. to situations for which they were not designed).

⁴¹ Note that the purpose of the model here is primarily illustrative. Some further relationships (e.g. the impact of rain acidity) were not considered at the time of the analysis. However, this is secondary to the methodological issues which are central to this paper,.



An important caveat to Figure A1.2 (and all subsequent analyses in the present paper) is that it omits any consideration of assumptions and uncertainty. Virtually all analyses which attempt to extrapolate away from those points which have direct measurements rely to some lesser or greater extent on assumptions and even the most direct measurements involve some degree of uncertainty. The understanding and quantification of uncertainty and error along with the testing of assumptions is a vital part of any modelling research and a major element of the studies underpinning much land use research. However, such issues are not the central thrust of the present paper and we leave these aside with the caveat that such issues are clearly important.

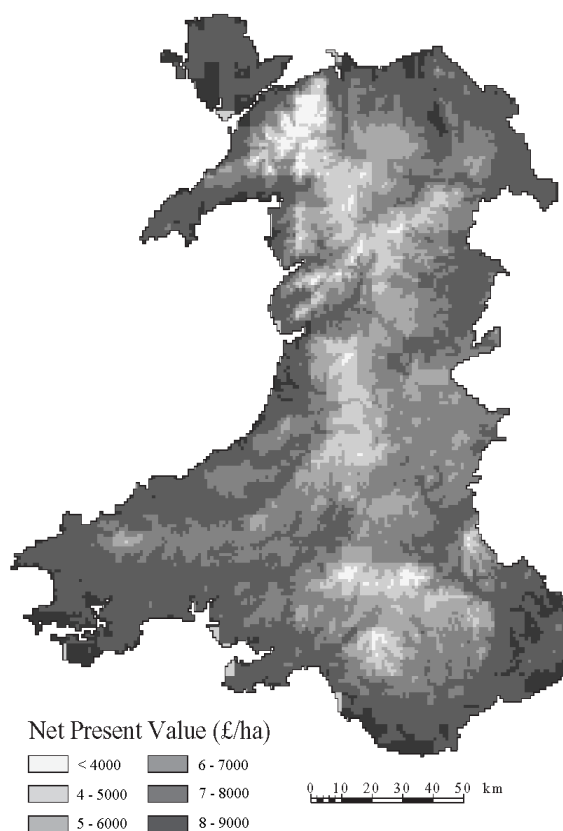
The calculation of the physical provision change effects of a given policy are only the first part of the benefit transfer task. We now need to convert these physical units into monetary amounts. In Section A1.3 we simply use prices rather than values (see the discussions of the main part of this paper for the distinction between these terms). In the case of forestry this analysis also allows us to introduce the issue of time as, of course, trees take a long time to grow. We also contrast the market price value of timber with that of agriculture which is the alternative land use in this analysis. By conducting all of this analysis using prevailing market prices we provide ourselves with an understanding of the present pattern of land use, which is of course driven by prices rather than underlying values. However, in Section A1.4 we make the transition to values by making the adjustment from market prices and by including those externalities which a move from agriculture to forestry would generate, principally the considerable change in carbon storage which would occur and the value of woodland recreation which would be created.

A1.3. From the change in provision to its market price and comparison with other marketed goods: Explaining the status quo.

The move from provision change to market price is an interesting one in the case of timber and illustrates the need to consider the temporal dimension. While the price of timber is readily

available from the market⁴², even the fastest growing trees will take more than 40 years from planting to maturity. This means that in assessing the 'net present value'⁴³ of a potential investment, the land owner will substantially discount the delayed felling revenues of a woodland whereas the costs of establishment, which principally occur at the time of planting, are virtually undiscounted. While there are well established procedures for assessing present values in such situations, the rate of discount is a key factor here, with higher rates resulting in lower present values of delayed net benefits. Furthermore, the discount rate used by a private investor assessing market returns is likely to be much higher than the 'social discount rate' used by public decision makers which reflects a longer time horizon. While it is the social discount rate that is relevant to policy makers, in modelling the status quo it is the private discount rate which is relevant to explaining the present pattern of land use. Taking these factors into consideration allows us to move from the quantity provision map of Figure A1.2 to the corresponding value map of Figure A1.3.

Figure A1.3: Net present value of afforesting land across the study area.



While Figure A1.3 shows the net present value of the long term costs and revenues of changing land use to forestry, most farmers prefer to assess options on an annual basis. A simple relationship exists to translate between long term net present value and its annual equivalent (for details see Bateman et al., 2003). This 'annuitizing' procedure translates the long term values of Figure A1.3 into annual equivalent values ranging from about £50/ha/year up to around £175 /ha/year, these being distributed in a pattern similar to that of the net present values. In effect this means that any farmer who can generate annual

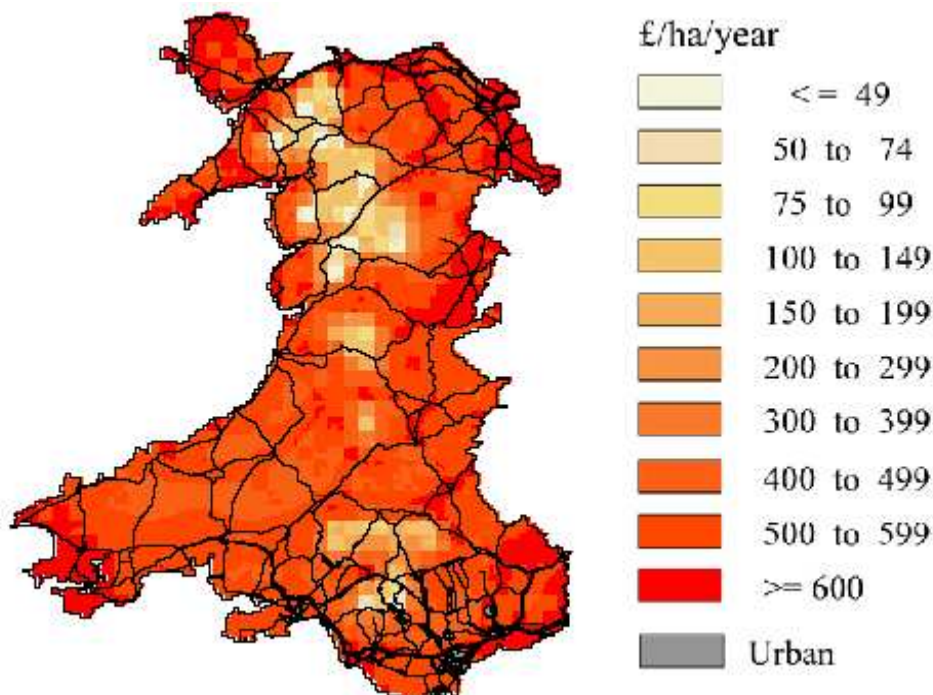
⁴² An unusual complication is that, unlike most goods, timber does not have a constant unit price. The price of a cubic metre of timber when composed of small trees is less than when that volume is cut from a single tree. This relationship is captured in a 'price-size curve' and is taken into consideration in the results shown here.

⁴³ The net present value of an investment subtracts the costs from the revenues in each year and then discounts these net benefits back to their present day equivalent. Summing across all years of the investment gives the net present value.

incomes in excess of this from their present farming activities is unlikely to change land use into woodland unless they are given some additional inducement.

To estimate the value of current agriculture we adopt a similar modelling approach to that taken for forestry. Data on farm activities are taken from across the country and modelled using statistical techniques which again link these to the physical environment, management and other variables characterising each area. Output prices and costs are then used to estimate the profit which farmers achieve from their present activities. As before we can then use our model to estimate farm profits for each location in the study area. Figure A1.4 illustrates predicted income from the present agricultural land use.

Figure A1.4: Predicted farm gate income from present land use⁴⁴



Source

It is important to emphasise that the farm gate income illustrated in Figure A1.4 is heavily influenced by prevailing agricultural policies, most notably the EU Common Agricultural Policy (CAP). This policy strongly distorts the price of agricultural outputs (and more indirectly their production costs) away from what they would be under free-market conditions. This means that we need to distinguish between the price of a farm product as received by the farmer⁴⁵ (which will of course have a major influence upon that individual's land use decisions) and the social value of that produce. The latter adjusts for the various subsidies and price interventions induced by policy, the logic being that such payments are simply transfers from one part of society to another. A problem is that such transfers can very strongly influence behaviour and indeed policies such as the CAP have radically affected the pattern and intensity of agricultural land use in the UK. Many economists argue that this distortion can result in major differences between the market prices which farmers respond to and consumers pay and the free-market prices which would hold in the absence of such distortionary policies. The latter, it is argued, would avoid distortions of land use away from those induced by underlying social values.

Although ongoing reform of the CAP is attempting to move farming back towards being a more market led enterprise, it currently remains far from being a free-market activity. Any cost-benefit analysis of the social value of land use should therefore adjust for such distortions and indeed the above analysis is subjected to such an adjustment by Bateman et al., (2003). This shows that the effect of the CAP is to inflate the value of certain types of agriculture relative to other land uses. For the purposes of the present paper we avoid the necessarily complex detail which such an adjustment process requires and simply note that not only is land use pattern influenced by spatial variation but also by market distortions⁴⁶.

⁴⁴ Farm income varies across sectors with Figure 4 illustrating the results for dairy farms. Bateman et al., (2003) also presents results for other sectors.

⁴⁵ Of course farm gate prices are substantially lower than those paid by consumers. For recent analyses see London Economics (2004).

⁴⁶ Indeed this case is particularly complex as not only does spatial variation in the natural environment affect land use, but also the levels of distortionary subsidies available also vary according to location. Unfortunately, that variation in subsidy is not guided by non-market benefits such as the carbon consequences of land use

Comparison of Figures A1.3 and A1.4 contrasts the outputs of forestry and agriculture as valued using prevailing prices (i.e. those which hold under existing policies and which determine farmers' land use). Recalling that the market value of forestry (its timber value) provided an annual equivalent of between £50/ha/year and £175/ha/year level we can see that this is lower than agricultural values in all but the central upland areas. It is therefore not surprising that the real world reflects this pattern very well with forestry generally confined to the central uplands and agriculture dominant elsewhere. We can therefore conclude that:

- (i) Land use patterns reflect the profits which farmers and other land users can obtain from the different outputs they can produce from their land⁴⁷;
- (ii) Those outputs are in part determined by the physical environment characteristics of land and this varies significantly by location
- (iii) Capturing that spatial variation of the physical environment is a vital element of land use assessment, planning and management.

In this particular case the prevailing set of prices and subsidies result in very little land being allocated to woodland rather than agriculture⁴⁸. However, this may very well not reflect the true social value of these alternative land uses. To estimate this two important adjustments need to be made:

- (a) Assessments of the social value of land use should not solely rely upon prevailing market prices. While these are important in understand why the present mosaic of land use is as it is, such prices are liable to be distorted by policies which provide subsidies or change prices of certain outputs. Social value assessments should adjust for such distortions.
- (b) Assessments also need to consider those costs and benefits which are 'external' to the producer and hence not reflected in existing costs and prices. These externalities include items such the impact of production on greenhouse gases or open-access recreation provision. The values of such items are not reflected in the farmers profits but they do represent genuine value flows to society and therefore have to be considered by the social decision maker.

In subsequent analyses we undertake the adjustments to allow for market distortions as outlined in (a) above (see for example panel (iv) in Figure A1.7). We now move on to consider methods of assessing the externalities identified at (b) above.

4. From prices to values and the incorporation of externalities.

From the main body of this paper we know that a social planning perspective requires that we consider values rather than prices. Therefore we have to take into account any consumer

(discussed in this paper) but by rather simple attempts to compensate for the impact of poorer land on farm incomes. This in turn results in further over-exploitation of certain areas, for example over-grazing of upland areas irrespective of their potential value as biodiversity habitat (see discussions in Bateman et al., 2003).

⁴⁷ This is hardly surprising and conforms well to the classic insights of Von Thünen (1826).

⁴⁸ A further important factor is that empirical analyses show that farmers require a significant profit premium before they will move into a long term and relatively irreversible activity like timber production (Bateman et al., 2003). This has been made worse by the UK Forestry Authority frequently only issuing felling licences on condition that the land is replanted with trees.

surplus associated with both agriculture and forestry. Bateman et al., (2003) undertake such an analysis the details of which we will avoid here. However, one of the key issues which that analysis does highlight is that conventional agricultural production is the recipient of substantial government payments in the form of price support (although this is declining rapidly) and direct income subsidies (which have recently increased⁴⁹). While a number of important arguments can be put forward to defend such intervention, it is also true that these transfers from the taxpayer might reasonably be reallocated to any number of alternative uses. Therefore cost-benefit analyses typically remove such transfers as part of the process of moving from private price based assessments to social value led decision making. Thus we find that the social value of agriculture in parts of the case study area is lower than its apparent market value.

The move to values and the removal of subsidies and other transfer payments significantly sways the cost-benefit balance towards forestry rather than agriculture. This move is substantially enhanced when we extend our analysis to consider the external benefits and costs of both agriculture and forestry. While a full cost benefit analysis would need to consider all externalities, for simplicity we will consider just two of the external benefits of forestry, carbon storage and woodland recreation, as together these illustrate the remaining key concepts which need to be considered here⁵⁰.

Carbon storage generates value by ameliorating climate change and its impacts. There are typically three aspects of carbon storage and loss arising from any land use change, all of which were assessed here⁵¹:

- Carbon storage in living crops: As plants and trees grow so they store carbon in their biomass. Although different plants have different density and carbon content, as a simple guide, the greater the biomass of the plant so the greater the amount of carbon it stores. Obviously this means that trees store far greater levels of carbon than typical agricultural crops (indeed livestock contribute to greenhouse gas emissions).
- Carbon liberation from finished products and waste: Once a plant stops growing or is harvested the process of carbon liberation begins. For most agricultural crops all of the carbon sequestered during the growing period is liberated back to the atmosphere relatively quickly following harvest. For trees the situation can be very different. While some tree species are put to enduses where all carbon might be liberated within a few years, other species are put to longer lasting uses such as construction, furniture, etc. Such enduses may keep carbon locked up for long period of time (again meaning that we have to consider discounting when we come to value this sequestration).
- Soil carbon gains and losses: Intensive agriculture tends to degrade the carbon content of soils whereas tree planting tends to enhance it. An exception occurs when trees are planted on wetlands and peats. Here the process of planting trees can lead to peat soils drying out and liberating the high levels of carbon they normal store. Tree planting in such areas can actually result in a net liberation of carbon with soil losses exceeding living biomass gains.

The long time periods concerned in the above processes means that our analysis has to embrace the temporal dimension (trees have long rotation periods and some soils take many years to fully adjust to new carbon balance after land use change). Bringing this together with the growth rate models of Figure A1.1 allows us to generate models and map results for the

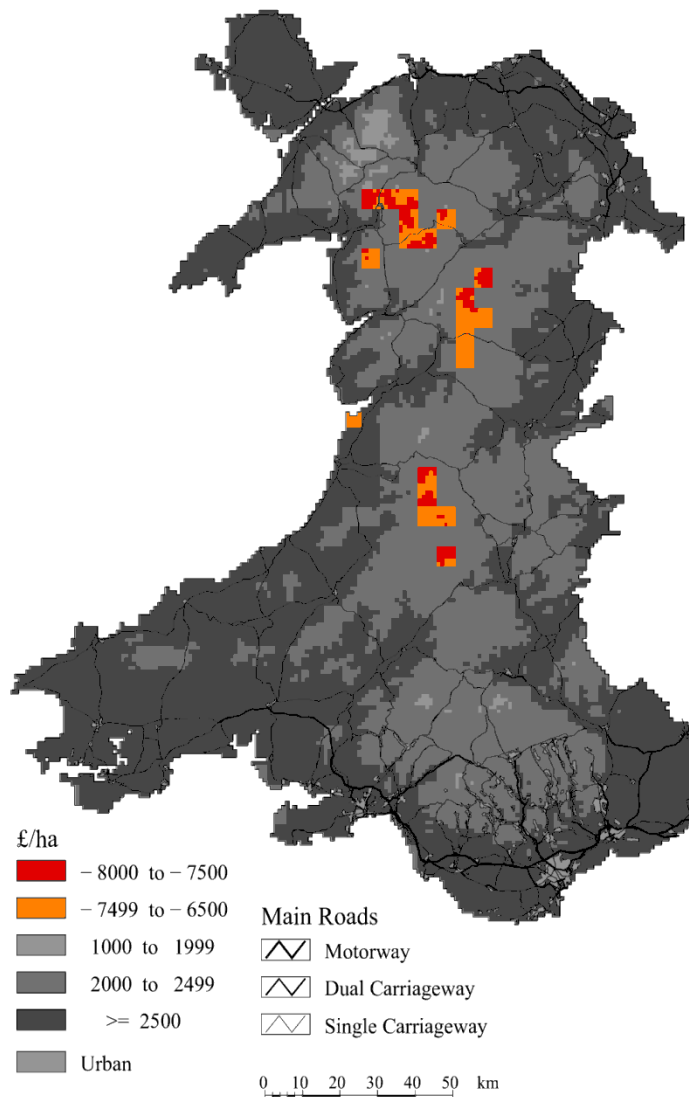
⁴⁹ For example the EU Single Farm Payment scheme introduced in 2005-06.

⁵⁰ Other key externalities include diffuse water pollution from agriculture (see, for example, Hutchins et al., 2009), social cohesion and impacts upon biodiversity.

⁵¹ Note that this does not embrace non-carbon effects such as the nitrogen cycle. These should be addressed in any full application but their omission does not undermine the methodological illustration given here.

change in net carbon balance arising each year as a result of land use change from agriculture to woodland. We then have to convert that change in carbon (the provision change) into values. Fortunately there is a large literature on the value of sequestering a tonne of carbon. These studies estimate the damage which climate change will cause and from that derive the value of reducing one tonne of carbon. Applying these values to our provision change estimates allows us to generate maps such as Figure A1.5 which shows the value of net carbon sequestration caused by land use change from agriculture to woodland. As can be seen, in areas of high tree growth rates so the carbon storage values are highest. As we move to higher elevations (near the central mountain spine of the country) so tree growth falls and with it the value of carbon sequestered. In those areas of peat soils (generally near the tops of the mountains) the carbon loss from those soils substantially outweighs the amount sequestered in livewood resulting in a net loss of value if tree planting occurs in such areas.

Figure A1.5: Net carbon storage values from land use change to forestry.



Source: Bateman et al., (2003)

As discussed in the main body of this paper, the marginal utility of a good describes the benefit which individuals obtain from a unit increase in provision of a good. For goods such as timber and carbon storage the levels of production which could be generated by afforestation of even the entirety of a large area such as Wales would have a negligible

impact upon the marginal utility of further production. To prove this consider the volumes of carbon which could be fixed by such an undertaking relative to the many, many times greater magnitude of carbon storage which is required to even begin to offset the problems of present and more particularly future climate change. Analyses such as those by Sedjo, et al., (1997) show that even afforestation of the entire USA would be far from sufficient to generate the sequestration required to address global warming. Therefore, the marginal benefit of further sequestration would stay roughly constant before and after any plausible level of afforestation. Hence the task for the decision maker is to obtain a valid estimate for the sequestration of one tonne of carbon and apply this to the estimated change in physical provision of such services.

From the above discussion we can see that the marginal value of a tonne of carbon stored will remain constant both as the number of tonnes stored increases and irrespective of where that carbon storage occurs. Neither of these characteristics applies to woodland recreation. Recreation benefits, like many goods, exhibit significantly diminishing, spatially confined, marginal utility; the benefit of creating one new recreational forest in an area significantly reduces the benefit of creating a second nearby recreational forest. Although this effect is quite obviously of potentially major significance, there is a paucity of good valuation evidence regarding diminishing marginal utility (and hence diminishing marginal WTP) for most non-market environmental goods. Nevertheless, those studies that have examined this issue find it to be highly significant (e.g. Egan et al., 2009; Lanz et al., 2009). In effect, the greater the provision of a good the more satiated we become with it and the lower the marginal utility (and hence marginal WTP) of that good.

The above phenomena does not just apply to changes in provision of the good under evaluation, marginal utility can also decline because of the presence of substitute goods. For example, while the provision of woodlands can generate benefits by providing recreational walks, these will be at least partially substituted for in areas where there are riverside walks. As Jones et al., (2002) show, this substitution effect can arise from quite diverse resources including man-made recreation sites and urban attractions⁵².

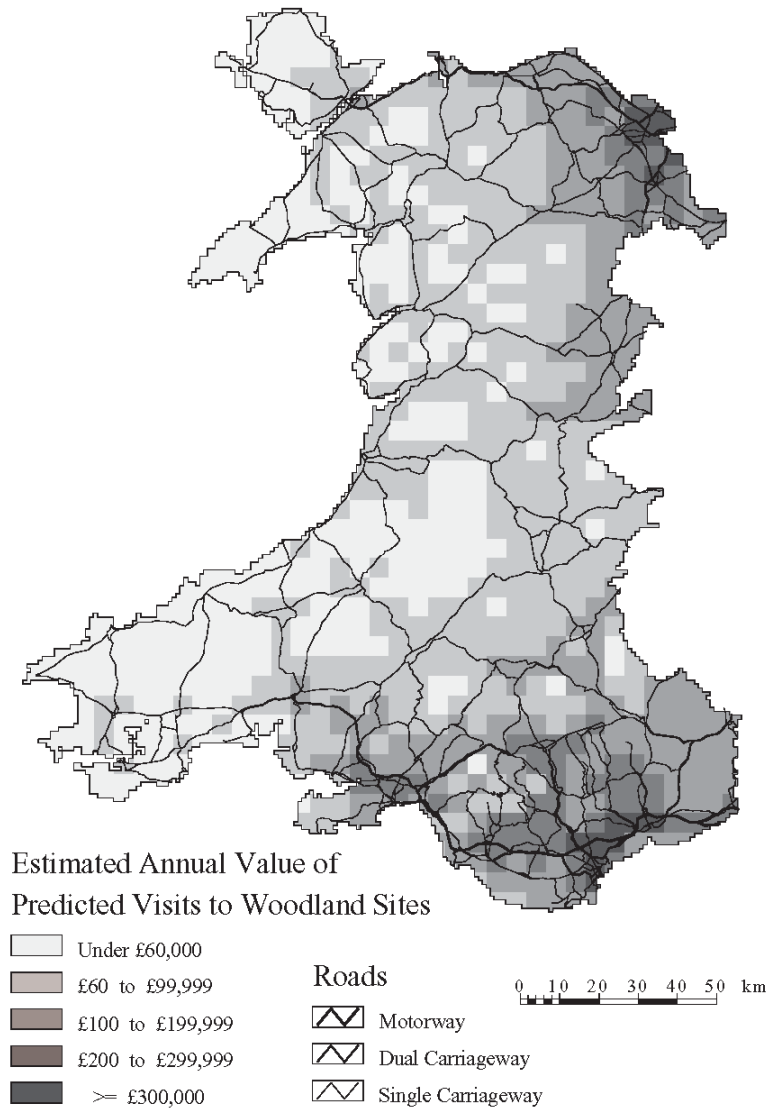
Even in the absence of substitutes, location matters with regard to spatially confined goods such as recreation. The further away a new recreational resource is from an individual the greater will be the travel and time costs of accessing that good and so the lower their WTP. This effect will be heightened by a poor quality transport infrastructure system. This creates the phenomena of distance decay (Bateman et al., 2006). This can be observed very clearly if we examine the pattern of recreation values which would be generated by land use change from agriculture to woodland. By undertaking a revealed preference study of visitor behaviour we can observe how increasing travel time and associated costs progressively reduce the willingness of individuals to visit a site. Furthermore, given that travel costs can be expressed in money terms we can observe the trade-off between money and visits; in other words we can infer the value of those visits. We can then use this model of behaviour and, taking into account the distribution of population and the road network and its quality, we can predict the number of visits and their value which would be generated by placing a recreational woodland at any given location taking into account. Figure A1.6 illustrates results from this analysis⁵³. As would be expected, the pattern of recreation values shown

⁵² Note that complementary relations can also arise. For example forests with lakes may attract additional visitors.

⁵³ The interpretation of the recreation map is not as straightforward as for say the carbon map. Whereas we can simply sum the values shown on the later map to get the carbon value of afforesting any given area or indeed the whole country, this is not the case for the recreation map. As discussed above, once a recreational woodland is located in any given area this then serves as a substitute for any further nearby new woods and would therefore depress marginal WTP for the latter. The estimation of values for the creation of multiple recreation sites has to take into account this substitution effect. This caveat needs to be kept in mind when

strongly reflects the distribution of population with the highest values being in the south east (around the largest Welsh city of Cardiff) and the north east (reflecting the proximity of Liverpool and Manchester) while values along the central upland spine and the remote west coast are relatively small.

Figure A1.6: Estimated annual recreational value of land use change into woodland⁵⁴



considering our spatial cost-benefit analysis in Section 5. While the results shown here are valid, recreation values would alter if partial implementation of the land use change was to be undertaken.

⁵⁴ A complication is that the marginal recreation value per hectare is likely to be a complex and ultimately sharply diminishing function of the size of that woodland. There may well be a minimum threshold size for a woodland to deliver recreational benefits such that the initial hectare may actually have lower marginal value than the second hectare. However, once a woodland is of a sufficient size to generate trips, then the marginal per hectare value is likely to decline rapidly. This intuition flows from the common observation that the majority of recreation visitors do not wander far from the access point or car park of the site (Coombes, et al., 2009). This means that simple estimates of per hectare recreational value, derived by dividing aggregate WTP by the area of a site, are likely to be erroneous. As a partial response to this problem, in subsequent analyses we calculate recreational values on a per site rather than per hectare basis by assuming that a substantial (say 100ha) site is created in each 5km square of the Ordnance Survey grid. This avoids the indefensible linear relationship between total and per hectare values mentioned above, although we acknowledge that there is a need for greater research to quantify the relationship between site size and value.

Given the importance of distance decay, substitution effects and consequent diminishing marginal utility and WTP we discuss these issues further in Annex 2 to this report. We now conclude by bringing together the internal and external values (rather than prices) generated by a land use change from agriculture into woodland, using our spatial approach to emphasise those areas that yield the highest net benefits from such a policy.

A1.5. Bringing it together: A spatial cost-benefit analysis of land use change.

We have now moved our analysis from simple consideration of market prices to a value based analysis. Furthermore, we have employed a spatially sensitive methodology which incorporates the vital issue of location throughout our analysis. Because all values are expressed in common monetary units and each value stream is spatially referenced, we can now sum our values.

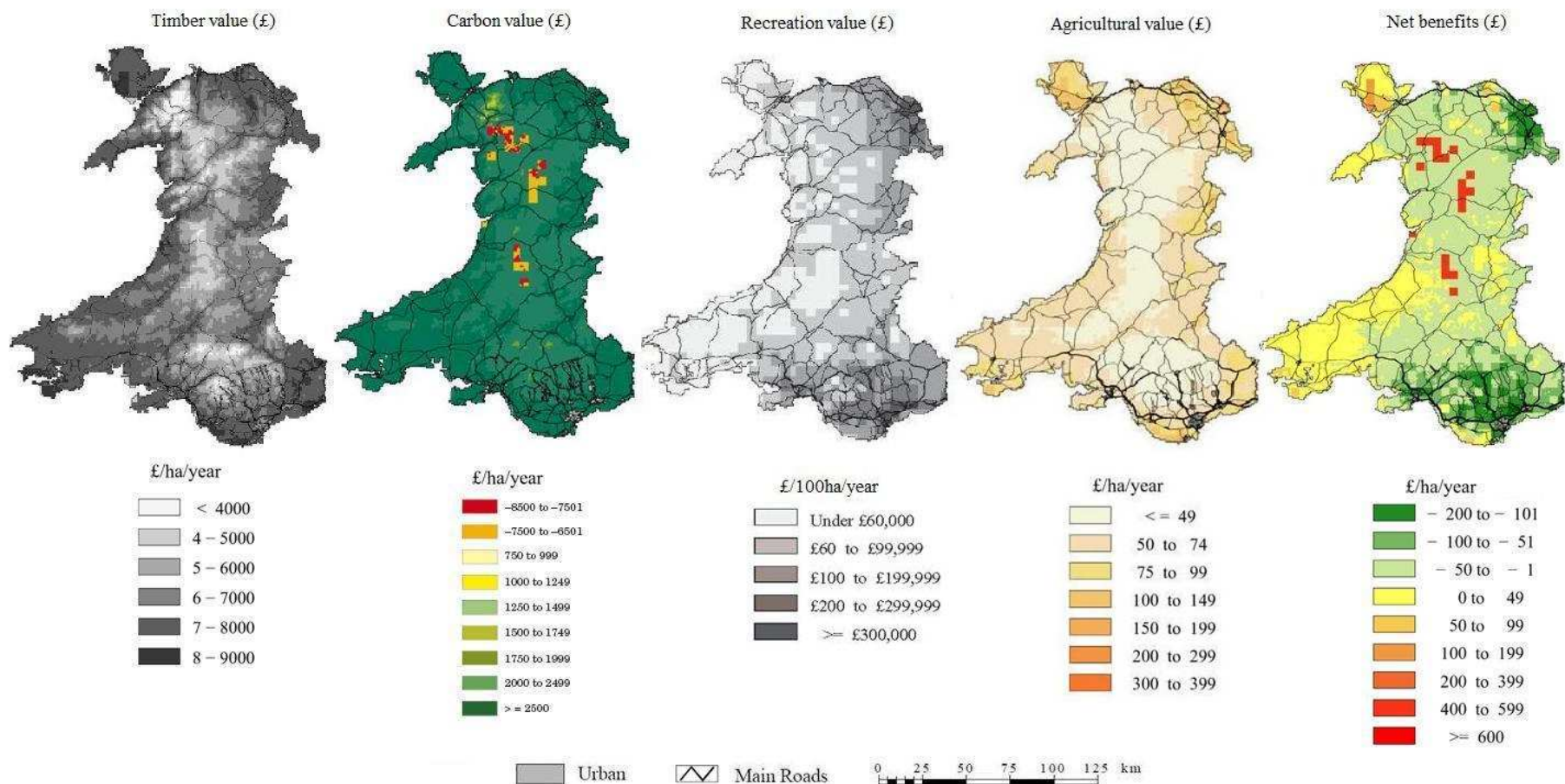
Figure A1.7 provides a visual representation of this analysis. In maps (i) to (iii) we detail the timber, carbon and recreation values which would be generated by multipurpose woodland. Map (iv) shows the social value of an existing agricultural land use (sheep) once we have subtracted the various price distortions, subsidies and other transfer payments arising from policies such as the CAP (to ensure a fair comparison we have also removed any transfer payments associated with woodland). Map (v) provides a cost benefit analysis which is obtained by summing all of the woodland values and subtracting this from the agricultural value. Here negative values indicate areas where the agricultural value is lower than the sum of woodland values. These cases are coloured with various shades of green, the darker areas indicating locations where woodland values most substantially outweigh agricultural values. As can be seen, our analysis shows that substantial areas of the country would indeed yield a higher social value under woodland than they do under agriculture. This result arises because we have now removed subsidy payments (which most heavily favour agriculture) and included two of the major externalities of this land use change; the storage of carbon and the creation of recreation benefits. There are further externalities that should be considered, but if anything they seem likely to reinforce and strengthen this result (e.g. we have omitted the external costs of diffuse water pollution⁵⁵ from agriculture and the external benefits of certain (although not all) types of woodland in terms of biodiversity habitat creation)⁵⁶.

The net benefits result of Figure A1.7 is in marked contrast to the market price outcome of the current status quo discussed previously where agriculture dominates the rural landscape. Because land owners do not receive payment for the carbon storage and recreation values which would be created by land use change, and because agriculture is currently much more heavily subsidised than forestry the market price solution is heavily skewed towards agriculture in most lowland areas. Indeed if we contrast this map with that of Figure A1.1 we can see that the failure to consider externalities has resulted in a situation where forestry is confined to the upland central spine, away from those populated areas where recreation values are highest and, perversely, concentrated in just those areas where woodland can result in net carbon emissions due to planting on peat soils.

⁵⁵ See, for example, Harris and Heathwaite (2005), Lane et al., (2006).

⁵⁶ Other important omissions include consideration of the long term dynamics of any change in terms of feedback effects as well as consequences for other land uses arising from any particular land use change.

Figure A1.7: Spatially explicit cost-benefit analysis of a potential land use change: Retaining agriculture as opposed to converting to multi-purpose woodland



Notes: From left to right the maps show (i) The annualised equivalent of the social NPV of timber arising from a perpetually replanted woodland; (ii) The annualised equivalent of the social NPV of net carbon flux (live wood, products, waste and soils) under woodland; (iii) Estimated annual value of predicted visits to woodland sites (calculated on a per site basis – see notes to Figure 6); (iv) Predicted subsidy adjusted (shadow) value of sheep farming; (v) Cost benefit analysis of retaining sheep farming as opposed to conversion to woodland (defined as timber, carbon storage and recreation). Here negative values (shown in dark to light greens) indicate areas

where woodland values exceed agricultural values, while positive values (shaded from yellow to red) indicate the opposite result highlighting areas which should stay in agriculture. Further details given in Bateman et al., (2003). Source: Bateman (forthcoming).

Annex 2: Distance decay and substitution effects

The benefits generated by any environmental improvement associated with land use change can be described through a spatially explicit valuation function. This measures the value of the improvement as individuals' willingness to pay (WTP) for that change. The function relates that WTP to the factors which determine it. These include:

- (i) The quantity or quality change being considered (reflecting the higher utility of large provision changes);
- (ii) The distance between the site of the improvement and the individuals' home (reflecting the higher costs of use associated with more distant goods – this may be exacerbated if as distance to the improvement increases so distance to alternative substitute decreases);
- (iii) The individuals' income (reflecting the individuals' ability to express their WTP);
- (iv) Other relevant variables

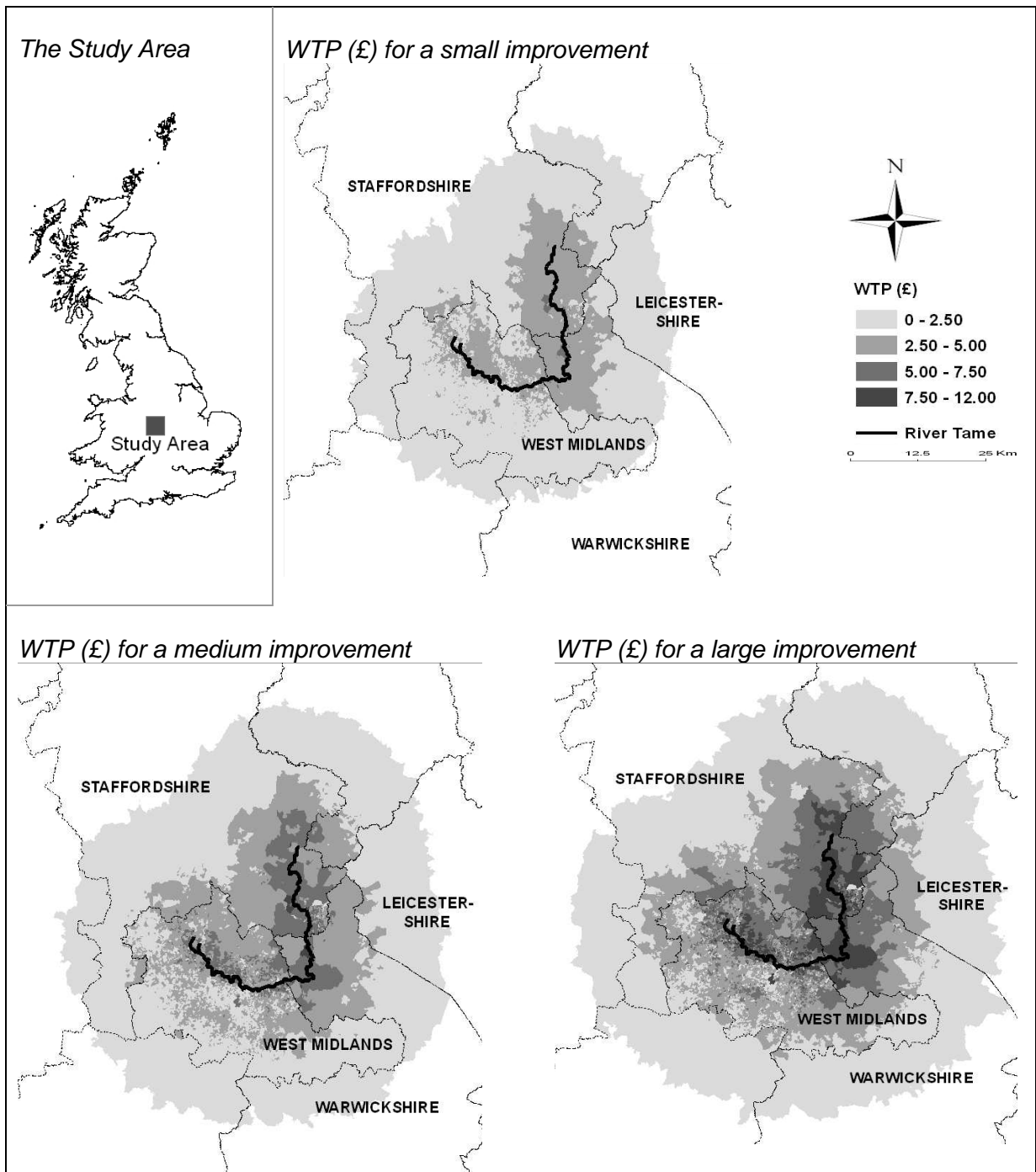
Figure A2.1 illustrates maps of WTP derived from such a value function estimated for improvements to the quality of the River Tame in the Midlands of England. Data for this analysis was obtained from a public survey employing a stated preference valuation method which directly elicited WTP for the improvement in question⁵⁷.

The analysis considered three levels of improvement which for simplicity we will refer to as the 'Small', 'Medium' and 'Large' improvement. Consideration of the first of these maps for the Small improvement shows that the values generated are highest nearer to the river and decrease as distance from the river rises. This is the 'distance decay' effect (Bateman et al., 2006a) which reflects the increasing travel costs of accessing the river from more distant locations. Again this result shows the clear necessity of considering spatial issues in the assessment of any change in the physical environment. Distance decay is also clearly visible in the maps of the Medium and Large improvement and contrasting the three we can see the increased values generated as the scheme size grows⁵⁸.

Figure A2.1: Maps of estimated mean WTP (per household, per annum) of Census output areas for various water quality improvements

⁵⁷ The study used the contingent valuation method. For details of the study see Bateman et al., (2006a). The study also illustrates the vital necessity of including spatial issues when aggregating upon from individual WTP to the social value of a project, showing the gross errors that can occur if such issues are ignored.

⁵⁸ To date relatively few valuation studies have considered the issue of distance decay although exceptions include Bateman, et al., 2000b, 2005, 2006a; Hanley, et al., 2003; Imber, et al., 1991; Loomis, 2000; Mouranaka, 2004; Pate and Loomis, 1997; and Sutherland & Walsh, 1985. These findings suggest that distance decay can be approximated by a nonlinear function in which the slope indicates that values decay relatively quickly with increasing distance but that the rate of decay itself falls such that statistically significant if low values can arise some distance from the improvement site. The distance at which values fall to zero (defining the 'economic jurisdiction' of an improvement project; Loomis, 2000) is reflected in the intercept of the distance decay function which increases with the scale of the improvement. Ongoing work by Carlo Fezzi and Silvia Ferrini at the RELU ChREAM project investigates non-parametric distance decay functions although these still fit conform to the general pattern described above.



Source: Bateman et al., (2006a)

The map for the Large improvement also most clearly shows the impact of income upon WTP. Examining areas of similar distance either side of the river (i.e. controlling for the distance decay effect) one can see substantial variation in WTP. This reflects the diverse range of incomes across the study area with higher incomes areas more readily able to express their WTP values for the improvements in river quality. This variation reflects the realities of life; that richer groups can afford to access more goods, be they market priced or environmental. However, policy makers can, if they wish, decide to adjust for this factor (for example if it is felt that access to environmental goods should not be determined by ability to pay). This can be readily

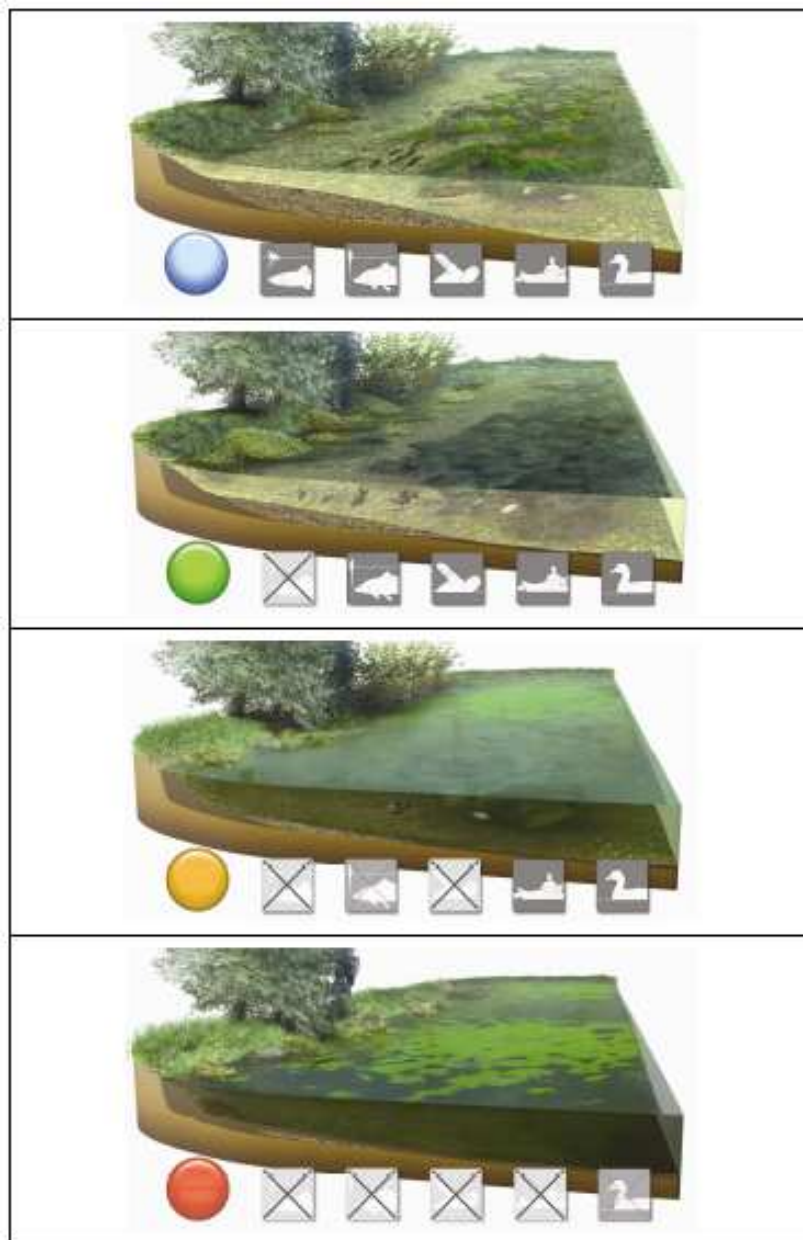
achieved within the analysis by reweighting the WTP responses such that poorer groups receive a higher weight such that the effect of income distribution is cancelled out. This is a social decision which is entirely in line with economic analyses if this does indeed reflect society's preferences⁵⁹.

The above analysis clearly demonstrate distance decay, but the maps do not show the impact which substitutes can have upon values. In effect the presence of a substitute can be thought of as heightening the distance decay effect. The closer an individual is to a substitute, the less their WTP for some new alternative. When that alternative is some distance from the individual, and particularly if it is further away than the existing substitute, then WTP is likely to decline substantially and may become zero.

This impact of substitutes across space is more clearly demonstrated in results from the RELU funded ChREAM project (Bateman et al., 2006b; Ferrini et al., 2008; Hime et al., 2009). This study again concerned river water quality employing the quality ladder illustrated in Figure A2.2 to convey river water quality levels. Here the highest quality water is represented by the picture with the blue coloured disc. A somewhat lower quality level is denoted by the green disc, then the yellow state and finally the worst quality is denoted by the red disc.

⁵⁹ Such income related utility weights are explicitly allowed for in the HM Treasury (2003) 'Green Book' guidance on cost-benefit analysis.

Figure A2.2: The water quality ladder



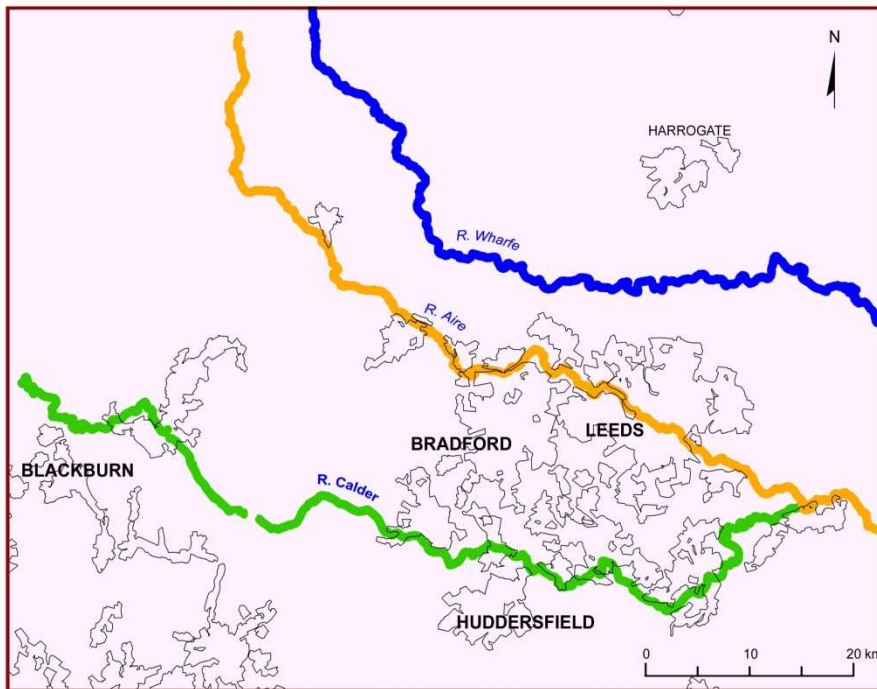
Source: adapted from Hime et al., (2009); copyright protected.

The water quality ladder was used to convey both status quo and potential alternative river qualities in and around the area of Bradford and Leeds in Yorkshire. A large sample survey of the study area shown in Figure A3 was used to examine the WTP for improvements in the quality of the River Aire, the middle of the three rivers shown. The survey used a stated preference approach to examine a number of permutations of provision change. At the time of writing, results from the survey are still being analysed so the following is purely illustrative based upon early results and prior expectations.

In Figure A2.3 the current status is that the River Aire is described as the yellow level of the water quality ladder, while the River Calder (to the south of the Aire) is

designated as green quality and the River Wharfe (to the north) is described as the best (blue) quality.

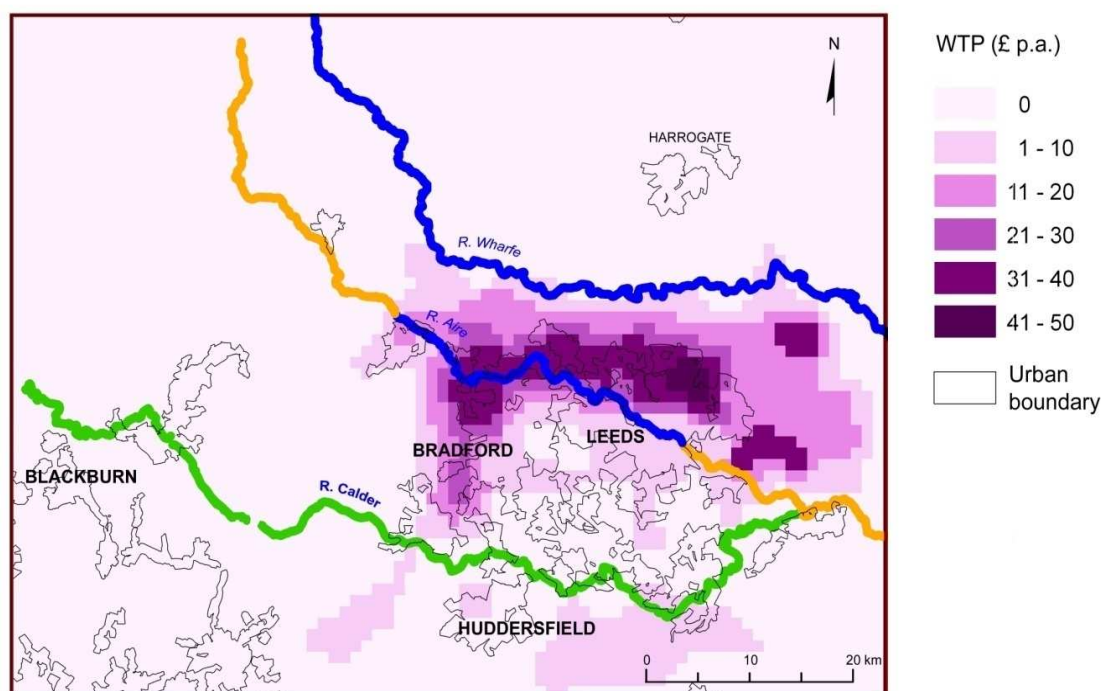
Figure A2.3: Baseline water quality



Source: Bateman et al., (2009c)

Figure A2.4 illustrates expected WTP per household per annum for a single stretch improvement in water quality as shown by the blue section of the River Aire. The pattern of values reflects all factors (i) to (iii) mentioned at the start of this Annex (provision change, distance decay and substitute availability; ability to pay). The provision change has generated significant positive WTP but there is a clear distance decay effect with values falling as distance from the improvement increases. There is also a clear substitution effect as values near to the high quality river Wharfe fall rapidly and are zero for virtually all areas north of that river. In contrast the substitution effect of the lower quality River Calder is much weaker and positive values are recorded even some way south of this river. Finally there is the clear effect of socioeconomic drivers such as income with WTP being substantially higher in the wealthier areas to the north of Leeds and Bradford than in the poorer inner city areas of both cities. As mentioned previously, we could add distributional weights to these results to compensate for the income inequality driving this latter pattern.

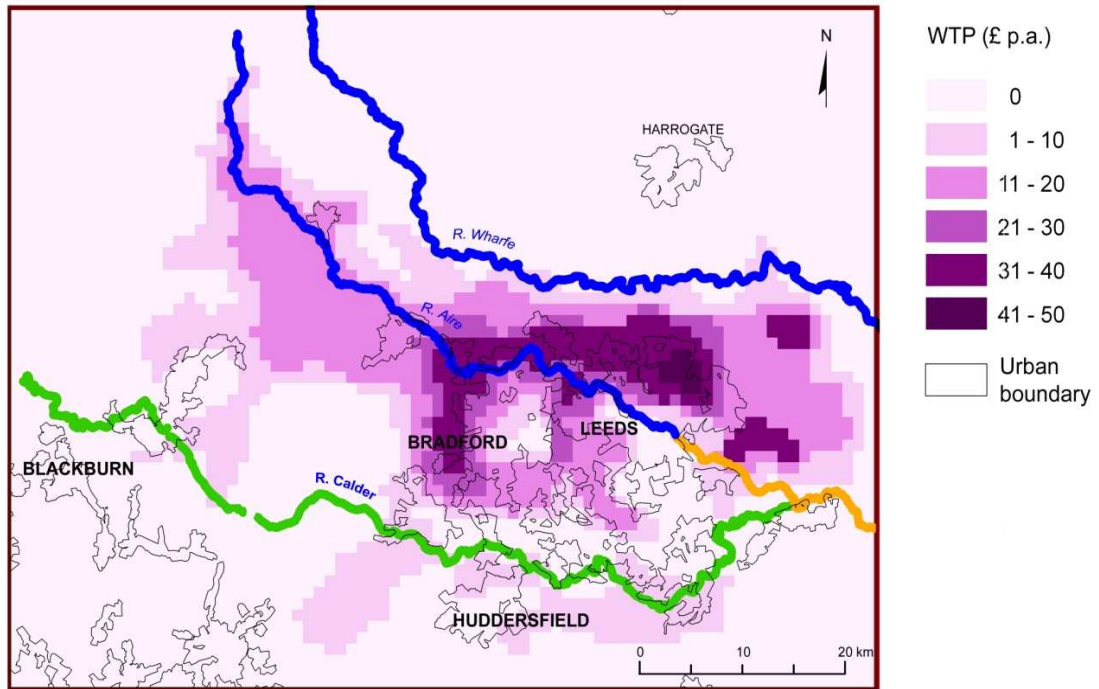
Figure A2.4: Map of estimated mean willingness to pay (per household, per annum), for a single stretch improvement in water quality on the River Aire.



Source: Bateman et al., (2009c)

Figure A2.5 illustrates predicted WTP per household per annum for a larger double stretch improvement in water quality as shown as the longer blue section of the River Aire. Again patterns reflect the factors captured in our value function, the main difference being the longer area of non-zero values now generated along the upper reaches of the Aire, although the relatively lower incomes of this area mean that WTP in this additional area is not as high as some of the high values near to the initial stretch.

Figure A2.5: Map of estimated mean willingness to pay (per household, per annum), for a larger (two stretch) improvement in water quality on the River Aire.



Source: Bateman et al., (2009c)

Annex 3: Letter and questionnaire soliciting initial information from natural science CLAs for economic assessment (to be sent and collated by NEA Secretariat)

Dear XXXX

Professors Steve Albon and Robert Watson have asked Prof. Ian Bateman (UEA) to direct the economic assessment for the NEA which will now run as a distinct but highly integrated stream of the overall project.

The economics team will appoint economists to work closely with each of the natural science streams. An initial aim will be to ensure that the economists have sufficient understanding of the various types of ecosystem service being assessed and how these will be quantified to ensure compatibility with economic valuation. To facilitate this Contributing Lead Authors (CLA) are asked to answer a few preliminary questions. Ian would like to stress that "in addressing these do remember that you are dealing with economists here and so short answers using small words would be much appreciated! Imagine you are explaining things to a young and non-too-smart kid and you should be on the right track!!"

The questions are items (1) to (7) below. However, to facilitate comparison across the various natural science streams these are formulated these into the table given at the end of this document, so please use that for your responses.

- (1) Confirm the general natural science area that you are assessing (e.g. enclosed farmland)
- (2) What services are generated by your natural science assessment area which you feel have some value to humans (this includes items without market prices; e.g. *carbon sequestration* may be unpriced but is clearly valuable)? Please list all of those services that you feel are relevant to your area.
- (3) Please indicate the units that you will use to quantify each of the services listed above (e.g. *net change in tonnes of carbon*)
- (4) For each of those services please give details of the spatial units that you will be able to provide (e.g. *net change in tonnes carbon per hectare*)
- (5) Will the units given in the previous question vary for different areas of the country? If yes please give an example (e.g. *tonnes of carbon per hectare in each 5km OS grid square*); otherwise just write 'No'
- (6) For each of the services in the first column please give an example of the type of data that you will be able to provide in each year of the assessment (e.g. *2009: net loss of 0.2 tonnes of carbon per hectare in arable areas of OS grid square XXX,XXX*).

Please send responses by 14th August to me at the UNEP-WCMC NEA Secretariat (email: Claire.Brown@unep-wcmc.org).

Thank you for your help with this important task.

Claire Brown

Questionnaire: Bringing natural science and social science together in the NEA

Please ensure that this questionnaire is completed and returned to Lucy Simpson (Email: Lucy.Simpson@unep-wcmc.org; tel: + 44 (0)1223 814 705) with a copy to your designated member of the economics team. All questionnaires have to be collated for presentation at the next NEA Expert Panel meeting in late October. Therefore this has to be returned by 23rd October 2009 at latest.

Natural science area: (e.g. enclosed farmland)	
Contributing Lead Author	

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Please list those services you are assessing which you feel have some <u>direct use</u> value to humans (e.g. <i>carbon sequestration</i>)..	For each of the services listed in column (1): Please indicate the units that you will use to quantify each service (e.g. <i>tonnes of carbon stored</i>)	For each of the services listed in column (1): Please give details of the spatial units that you will be able to provide for each service (e.g. <i>tonnes of carbon per hectare</i>)	For each of the services listed in column (1): Will the information in the previous column vary for different areas of the country? If yes please give an example (e.g. <i>tonnes of carbon per hectare in each 5km OS grid square</i>); otherwise just write 'No'	For each of the services listed in column (1): Will you be able to provide data on how this service has changed since 1945? If yes please give an example clarifying the time period (e.g. <i>Annual data: 1999 = net loss of 0.2 tonnes of carbon per hectare in arable areas of OS grid square XXX,XXX</i>).	For each of the services listed in column (1): Will you be able to predict how this service will vary into the future? If yes please give an example clarifying the time period (e.g. <i>Annual data: 2011 = net loss of 0.2 tonnes of carbon per hectare in arable areas of OS grid square XXX,XXX</i>).	For each of the services listed in column (1): Please indicate any goods or benefits that directly give value to humans which you think will arise from each ecosystem service irrespective of whether they have market prices (e.g. <i>timber, woodland walks, etc.</i>)

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