A Valuation of England's Terrestrial Ecosystem Services

Final Report

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Executive Summary

Key Messages

- This study aims to develop further the evidence base on the economic valuation of ecosystem services.
- There are many criticisms against the appropriateness of completing a total valuation of the benefits derived from ecosystems services. The approach outlined here highlights the issues faced in doing this and attempts to address them throughout the study.
- For policy decisions and an understanding of sustainability issues, an analysis of marginal changes which facilitates consideration of trade-offs and change over time is needed.
- The study adopted a service based approach. Whilst this has made it feasible to attempt to estimate the Total Economic Valuation (TEV) of England's terrestrial ecosystem services, the figures presented here are most likely to be lower bound estimates of the benefits received by society. This is due to the numerous difficulties with making such estimates and a number of gaps. The 'true' value, taking account of inter-linkages and thresholds and limits, is likely to be much higher.
- There are still significant gaps in understanding how benefits are derived from biophysical aspects of the ecosystem at different scales, as well as a lack of good, current data needed to value some of these benefits.
- It remains challenging to sum valuations for different benefits in different places and at different scales. More robust benefits transfer information may make this more practicable in future.

Conclusions and recommendations

The following **conclusions** are drawn from this study:

1. This research has **drawn together a significant body of information** on a wide range of benefits provided by England's ecosystem services. It has been possible to **categorise the final benefits received by society into a typology** that can be used by decision makers to ensure the widest range of benefits are considered in policy making.

2. Due to a number of limitations, it is considered that the values presented are likely to significantly underestimate the full value received by society from many of the services, some of which may in fact be infinite in value. Therefore **these values should be viewed as lower bound estimates.** For instance, the estimated value of the benefits provided by regulating services does not include any value for water purification benefits and only partially covers the value of the benefits provided by other regulating services;

3. It is clear that a total valuation is not useful in considering the implications of policy-related changes. However, given the gaps that remain in the overall framework, and the fact that supporting services can not be included within

the framework, **the suitability of a total valuation for advocacy purposes may also be questioned by some**.

4. **Total System Value** (TSV) **does not equal Total Economic Value.** The implication of this is that economic approaches alone can not be used to estimate TSV. The value of the additional benefits not currently captured within valuations needs to be considered in a qualitative manner in decision making. In order to facilitate this, the focus should be on generating a better understanding of the biophysical relationships along with limits and thresholds;

5. While the **analysis provides a significant amount of information on how ecosystem service benefits are realised by society**, as a result of the scope limitation of this assessment (i.e., a total valuation reflecting a snap-shot in time), **it has not been possible to consider trade-offs,** for instance between ecosystem services under different scenarios. The analysis can not show change over time, and therefore is of **limited use in addressing sustainability issues;**

6. A **services based approach** carries limitations as noted above, however, it also **provides the flexibility to use available data sources**. Haines-Young and Potschin (2008) investigate how the habitats and services based approaches can be brought together so that their strengths can be combined and used most effectively to support decision making. In doing so they consider the suitability of a 'place–based' approach. While that approach seems reasonable and worth further consideration, as it is not part of this research, it is not clear at this stage what valuation issues are likely to be encountered in making it operational (under either a total or a marginal assessment), nor is it clear how far it could overcome the limitations of the other approaches;

7. **Many theoretical challenges have been encountered in completing this assessment.** The most significant is that **economic theory suggests that change should be considered at the margin in order to inform decision making. This leads on to issues with the identification of an appropriate baseline** to facilitate consideration of the total benefits (this was a particular issue for the valuation of benefits from regulating services). While the baseline applied is suitable for use here, it is not necessarily very realistic in that there is no consideration of how alternative activities or behaviours would be used to replace lost welfare values under this baseline. Other major conceptual difficulties specifically relating to the valuation of benefits from regulating services concern the **attempt to identify the benefits over and above those provided under the baseline** (e.g. as was the case with the assessment of benefits from both air quality and water regulation services)**. This data is necessary in order to complete a monetary valuation of these benefits;**

8. As noted above, a significant limiting factor in this assessment is the **lack of clear information on the benefits arising from some services**. This hinges on a **gap in our understanding of the biophysical relationships** between aspects of the ecosystem and how final benefits are realised (e.g. benefits from regulating services, particularly water purification and waste treatment services);

9. In terms of how values can be aggregated, the key conclusions are: it is **inappropriate to use valuations that were estimated for a marginal change to estimate the total value at any scale of assessment** (local, regional or national). At best these estimates can be used as an indication of

the lower bound of the total value for illustrative purposes (as per Section 4.4.5). In addition, **care is required when summing values for different benefits that have been estimated using different valuation approaches** as this may cause double counting, or may result in an incorrect estimate of welfare values; and

10. While the best available monetary valuations were identified for application in many cases, **it can not be assumed that these values are directly relevant to the question asked here and/or that there is no further need to improve on these estimates for use in the future.** This is an obvious issue in recreation, where in some cases only one data source is available and/or where benefits transfer has been carried out using quite site specific WTP values. In other cases the valuations are based on relatively old data. Individuals' preferences may have changed since the time of the original study which further impacts the accuracy of the valuation. These possible changes in preferences cannot simply be accounted for by adjustments for income growth or purchasing power.

The following **recommendations** are made:

1. As concluded above, a total valuation exercise is not useful when considering policy implications and its usefulness for advocacy could also be questioned, given the limitations encountered in this study. **It is recommended that in future the focus should be on marginal assessments.** These types of assessments can be used to inform policy choices and for advocacy, if appropriately defined. For instance, for advocacy it may be more appropriate to consider the implications of a national policy and the value of changes which might result from it (e.g. Jacobs (2005) assessment of the benefits of conservation policy in Scotland);

2. There is clearly **a gap in our understanding of the biophysical relationships between some aspects of the ecosystem** and how final benefits are realised. This has resulted in difficulty in identifying the extent of the benefits provided at a regional or national scale. **Research into how services operate and interact at difference scales,** and how this interaction impacts on the extent of the benefits realised, would help in the valuation of benefits at these scales. This is a priority and therefore **should be used to inform future work in the biophysical assessments, and in the modelling and monitoring arenas,** in order to inform valuations;

3. There is a need to recognise the value of supporting services. **It would be worth investigating the possibility of developing a biophysical model of supporting services** to inform decision making;

4. Further **investigation should be carried out into how the 'place-based approach'** (outlined in Haines-Young and Potschin (2008)) could be made operational. Its potential advantages and disadvantages for valuation should be investigated, with specific consideration given to its implications in terms of data requirements and availability, for monetary valuation for marginal assessments; and

5. **Prioritisation of how the valuation gaps should be filled will depend on how acceptable the existing studies are considered to be.** This will vary depending on the purpose of the valuation exercise. Valuation data that are considered acceptable, and appropriate for use in benefits transfer in *this* case, given the reduced need for accuracy, may be considered inadequately robust or inappropriate where real policy choices are being made. For instance, although a gap has not been identified for a number of the

recreational benefit assessments, given their specific focus and/or age, the values available may be considered unacceptable for application where real policy choices are being made. This issue may or may not represent a greater priority than, for instance, the gaps identified with regard to the valuation of wild produce, therefore **it is recommended that a benefits transfer strategy should be developed to prioritise how the evidence base should be developed**.

This strategy should consider where efforts should be focused and what primary research is required. The following aspects are recommended for inclusion within this strategy.

- In order to provide for greater transferability of values it is recommended that **primary assessments of benefits be undertaken with benefit transfer requirements in mind**. There may be various ways of approaching this. One is through undertaking a number of assessments at varying locations to get an understanding of the variability in the values. This might help in identifying appropriate adjustments for benefits transfer. Another way is to use high level assessments, for example considering all recreational opportunities available to respondents at a higher scale, rather than seeking to value a specific recreational activity (say walking or cycling) at a specific site. Consideration should also be given to the appropriate scale at which the assessment should be carried out;

- This strategy could contain a requirement for all Government sponsored primary valuation data to:

    i. Be **uploaded to the EVRI valuations database**. While a useful source of information, this database currently does not contain many of the new valuation studies which may prove useful in making an ecosystems approach operational; and.
    ii. **Present benefits functions** in all final reports or papers, to enable adjusted benefits transfers to be undertaken.

- In order to facilitate consistent and comparable valuations, **consideration should be given to how the collation and presentation of standard statistics on MV and GVA could be adjusted to fit in with an ecosystems approach to decision making**.

Introduction

Defra's Ecosystems Approach project was undertaken to develop a more strategic approach to policy and decision making for the natural environment. This initiative has resulted in the publication of "Securing a healthy natural environment: an action plan for embedding an ecosystems approach", which details the steps necessary to embed an ecosystems approach in policy making.

This research on the valuation of England's terrestrial ecosystem services (which excludes marine, but includes both inland freshwater systems and estuarine systems) aims to develop the evidence base further in terms of the economic valuation of ecosystem services. Alongside this work, Defra has recently published an introductory guide to valuing ecosystem services (ES) to support the embedding of this approach (Defra, 2007b).

There are two key objectives for this research as specified by Defra:

- to provide an economic valuation of the '**total' annual value** of England's terrestrial and aquatic ecosystem services; and
- to move the field of ecosystem valuation forward through investigation of the existing evidence base, methodologies and limitations.

A total valuation is theoretically challenging to complete, and considered by some not to be a theoretically sound endeavour. Economic analysis to inform policy choices is typically concerned with marginal changes and the TEV framework is commonly applied in these analyses. Marginal valuation refers to a measure of the change (increase or decrease) in the provision of benefits under a given scenario.

The argument presented here is that where the purpose of the valuation is to compare contributions of capital stocks, as it is in this case, then the TEV framework as applied here is an appropriate (albeit imperfect) measure. So, while the valuation of the total benefits provided by England's ES may be considered by some to be meaningless, it is arguably appropriate given the project's objectives.

An overview of the total economic value estimates of the final benefits provided by England's ecosystem services is provided in Table A below. These values are considered to be lower bound estimates and, given the significance of the gaps in the overall framework and a number of other issues discussed throughout the report, it is *not* considered appropriate to present a summation of these benefits.

It is clear from Table A below that the benefits received from Provisioning Services appear to be the most significant in value, with benefits arising from the provision of recreational opportunities also providing significant values. However the results in Table A need to be interpreted with care.

The value of other benefits are very likely to be significantly underestimated due to issues encountered relating to the general approach applied (a total valuation) and to data limitations.

For instance, it is not possible to estimate a value for the benefits received from water purification services due to issues in identifying the total extent of these benefits above the baseline. This should not be taken to suggest no benefits are gained but rather that it is not possible to estimate and value these benefits.

The benefits presented for carbon regulation services are in fact marginal values, albeit covering a very large margin (grassland to woodlands). Furthermore, the flood defence benefits relate only to the value received from a subset of habitats, albeit the most significant habitats providing such services, so it can be assumed that the value represents a lower bound estimate.

Table A Welfare measure and/or contribution to the economy estimated for each ES benefit (£ million per annum)

	Benefit	Welfare Measures (constituent of Total Economic Value)			Contributions to the economy	Notes
		Approach 1		Approach 2		
		Market Value/ Expenditure	Consumer Surplus	Estimate of total WTP (e.g. damage cost avoided)	GVA /Income	
Provisioning	Agricultural food produce	8,213	-	-	3,478	**This estimate may change considerably from year to year as it is based on market prices which can fluctuate significantly.**
	Agricultural non–food produce	1,119	-	-	474	
	Non-agricultural cultivated produce	832	-	-	259	**Likely to be an underestimate as some of the estimates are based on single data sources and do not capture all of the benefits.**
	Wild produce	31.3	-	-	-	**Likely to be an underestimate as many of these benefits are realised in an informal and ad hoc way and are therefore unrecorded.**
Regulating	Carbon Regulation	-	-	1,007	-	**This valuation covers the benefits provided by woodlands, wetlands and peatland.**
	Clean air	-	-	0.018- 0.64	-	**Only values the benefits provided by woodlands, so it is likely to underestimate true benefit. At best this is a lower bound estimate.**
	Clean water	-	-	-	-	**No valuation was possible due to geographical scale at which benefit provision was being considered.**
	Flood control and storm buffering	-	-	1,243	-	**Relates to a subset of habitats, however these may be the most significant, so it can be assumed to represent a lower bound estimate.**
Cultural	Recreation	5,389	266	-	1,951	**This estimate can be considered to be a lower bound estimate.**
	Knowledge Systems	-	-	-	-	**No valuation was possible due to the conceptual issues associated with the total valuation approach and to the context-specific nature of how these benefits are realised.**
	Social use	-	-	-	-	
	Non-use	**-**	**-**	**-**	**-**	

Approach and methods

The total benefits from terrestrial ecosystem services in this study represent the benefits at a **snap shot in time** – one year. **No primary valuation** has been carried out as part of this assessment Valuations are built up using a variety of approaches including using market data, damage cost avoided estimates and benefits transfers of value, estimated through stated and revealed preference studies.

Other key aspects of the project scope are as follows:

- Under a total assessment, **no consideration of alternatives or substitutes** is considered. It is simply assumed that no alternative source of benefit is available;

- The assessment is **limited to the benefits from England's ES to England**;

- In order to complete the valuation exercise it is clearly **necessary to investigate the links between habitats, the ES provided by these habitats and other processes, and the resulting provision of benefits to society**. However, a detailed or broad ranging review of these links was **not considered to be within the scope of this project**;

- This research attempts to present the **value of 'actual' benefits received** by society wherever possible, for example, the quantity of food actually produced in one year or the amount of carbon actually sequestered in one year;

- In addition to providing significant benefits, **ecosystems can also have negative impacts on society's welfare**. For example, some plants and animal species are (rightly or wrongly) regarded as pests (e.g. biting insects, rats) and some carry disease (e.g. ticks) or are stinging or poisonous (nettles, some toadstools). These negative impacts from ES are considered to be **outside the scope of this project**; and

- This project includes the valuation of benefits received from ES that are not paid for within markets. Land management practices and production processes often create other external costs. For the purposes of this study, these could be considered to be second order externalities. These **second order externalities are outside the scope of this project.**

The starting point for this assessment is the definition of the **baseline, against which the total benefits of the status quo can be measured**. Conceptual difficulties arise in identifying a baseline that facilitates estimation of the total value of ES.

Strong sustainability proponents argue that it is impossible for man-made capital to serve as an adequate substitute for natural capital, such as the biosphere and ecological services. Guided by this principle, the baseline applied here contains an oxygen atmosphere, a hydrological cycle, and fresh drinking water supplies, the human requirement for a complex diet based on plants/animals, and a

comfortable climate. These components are therefore *not* valued within the assessment presented. The baseline for each category of service is defined below.

The study adopts a **'services' based approach**, under which the benefits arising from ecosystem services are assessed based on each specific ecosystem service at a spatial level appropriate to that service, rather than being based on a value per unit of habitat.

For instance, instead of considering the value of water regulation services based on the area of woodland providing these services, the value is based on the provision of water regulation services within a given area – such as a catchment – and provided by a variety of habitat types. Likewise for recreation benefits, instead of considering the recreational benefits based on the habitat that provides them, they are considered using more appropriate units such as participation rates. This approach allows for greater flexibility in the use of available valuation studies and data for benefits transfer, however, it also has limitations in terms of investigating the multifunctional aspects of ecosystem interactions. So, while making the valuation task more manageable, this approach can miss the complex interdependencies of how benefits are realised.

The **valuation is based on the TEV framework**, closely relating the list of services and benefits to the Millennium Ecosystem Assessment (MA). TEV is equal to market value plus consumer surplus. Consumer surplus is the difference between what an individual is willing to pay for a good or service and what he or she actually pays. The concept of consumer surplus is particularly important when estimating the benefits of environmental goods and services that have a low, or no, market price; these are referred to as non-market benefits. Where a good has no market price, the consumer surplus effectively represents the TEV of the good. An estimate of TEV is often built up by considering the direct benefits, the indirect benefits, and the non-use benefits provided by a good or service.

While the focus of this study is to provide estimates of the TEV, information on the economic impact of ecosystem services is also presented where possible, to provide important contextual data on the contribution of ecosystem services to the economy. The indicators of net economic contribution to society presented within this report range from Gross Value Added (GVA) figures, which net out producer costs from market values, to estimates of income and more complete Economic Impact Assessment estimates, which take into consideration multiplier effects and leakages.

The valuation of all the benefits arsing from ES follows a consistent **stepwise valuation process**. Following the identification of the baseline to be applied for each MA category of services (discussed below), the process has four basic steps, each discussed briefly below.

Step 1 –Define the service

Step 1 involves specifying the service and clearly delineating the components of the service that are of interest for the valuation exercise. This step is useful to assist conceptualising some of the more difficult benefits arising, such as clean air or clean water, where a large number of interacting components (e.g. emissions to air or to water) impact on the final realisation of benefits.

Step 2 –Describe and quantify the role that ecosystems play in the provision of the service and benefits. Understand and identify the extent of the service regionally and nationally.

This step needs to be based on a scientific understanding of the ecosystems concerned and how different processes interact to produce the service and the resulting benefits. Here it is necessary to identify the difference in service provision between the status quo (as things currently are) and the baseline scenario. Where multiple processes interact it is also necessary to delineate the role that specific ecosystems play in the provision of the service. This is particularly difficult for benefits arising from regulating services.

Step 3 – Quantify the benefits that stem from the provision of the given service.

As discussed above, it is necessary to identify the *final* benefits to society that are provided by the relevant service. In order to quantify these benefits it is necessary to understand how the service provides the benefit, and to link this to information on the extent of the service.

Step 4 – Identify the appropriate monetary value of the benefits and complete the valuation assessment.

Once the final benefits have been identified and quantified, it is necessary to identify appropriate valuation data to monetise these benefits.

The MA categorisation creates difficulties for valuation purposes, as categories can overlap. In addition, some services underpin others but still sit next to each other in the MA table, such as climate regulation and food, or climate regulation and disease regulation. For this reason it was necessary to develop a typology that, while building on the MA, facilitates the identification of final benefits and avoids issues associated with overlaps and double counting, amongst others.

The MA defines four categories of ecosystems services – provisioning, regulating, cultural and supporting. Each of these categories is discussed below.

Provisioning Services

Provisioning services are those that result in products being provided by ecosystems. These products include food, fibre, fuel, genetic resources, bio-chemicals, natural medicines and pharmaceuticals.

The **baseline assumption** is that foods, fibres, fuels, and other benefits from provisioning services are imported rather than available from England's natural resources. As the hydrological cycle remains in place under the baseline, the provision of water for abstraction, a benefit arising from the hydrological cycle, also remains within the baseline. Its value is therefore not captured within the total valuation exercise.

The Typology of benefits arising from these services is presented Table B.

Table B Typology of benefits from provisioning services

(TEV = Total Economic Value; MV=market value; GVA = Gross Value Added; '-' = not applicable or not possible to identify for reasons stated in Section 4)

Service	Benefit	Sub-benefit	Constituent of TEV	Valuation Approach	Contribution to the economy
Agricultural food produce	Cereal Crops		MV	Market data	GVA
	Vegetables				
	Fruit (including orchards)				
	Livestock	meat and diary			
	Game	pheasants/ grouse			
		waterfowl			
	Allotments			-	
Agricultural non-food produce	Fibre crops		MV	Market data	GVA
	Wool				
	Leather				
	Bio-fuels				
	Commercial cultivation of flowers and plants				
Non-agricultural cultivated produce	Aquaculture		MV	Market data	GVA
	Timber	wood and paper products			
		wood fuel			
		charcoal			
	Honey				Primary production†
	Medical raw material: yew				
Wild produce	Commercial on-shore fisheries (net and trap)		MV	Market data	Primary production†
	Peat fuel			Market data and price estimate	
	Wild mushrooms			Market data and price estimate	
	Non-food plants (rushes, reeds, sedges and bracken)			Market data	
	Other wild products			Market data	

Notes: † - no information on the producer costs associated with the collection or production of these goods identified, however these costs are assumed to be low. Therefore the value of the primary production is assumed to be an appropriate proxy to represent the value of the contribution to the economy.

Ecosystems support habitats and the diverse flora and fauna that exist there. Many goods are harvested from these habitats for human consumption, and the direct value of these goods to mankind is measured as an indicator of the value that ecosystem services provide by supporting them.

While there is a lot of data available on some provisioning goods, there is very little on others. In addition the data is often presented at different geographical scales or are inconsistent between sources, and it can be difficult to rationalise the details between sources. Values in these data sources are presented in both

market and basis prices and this adds additional confusion when interpreting the MV and GVA data of these goods.

Table C presents the estimated benefits provided by provisioning services.

Table C Market Value and Gross Value Added from benefits provided by England's provisioning services (£ million per annum)

Benefit	MV	GVA
Agricultural food produce	8,213	3,478
Agricultural non-food produce	1,119	474
Non-agricultural cultivated produce	832	259
Wild produce	31.3	-
Total	**10,195**	**4,211**

Owing to the limited data for wild natural produce and the absence of consumer surplus values for all goods, these values under represent the value of England's natural produce and are considered to represent lower bound estimates of their total value.

These values represent the benefits provided by the production of these goods, however they take no account of the negative impacts that production might have on aspects of the environment or on other ecosystem services.

Regulating Services

The MA defines regulating services as providing benefits obtained from the regulation of ecosystems processes. One reason why regulating services are important is that they provide 'infrastructure' and 'insurance' values. In many cases it is necessary to maintain at least a minimum set of these ecosystem services in order to ensure a reliable, sustainable, flow of the resulting benefits.

Natural systems are complex and dynamic with multiple roles and multiple stressors, which tend to behave in non-linear ways. This makes the regulating services from ecosystems particularly challenging to value due to the need to specify and quantify the role ecosystems play in regulating natural systems, such as air or water.

The inter-linkages between the provision of many of these services (for instance erosion control and natural hazard regulation) and between components of these services (CO_2 functions and O_2 production) make apportionment of the benefits to specific services and functions difficult, and in some cases inappropriate due to the assumptions required.

Therefore, the identification of a sensible baseline to facilitate the estimation of the total value (or something equating to the total value) of the benefits arising from these services is particularly difficult. The difficulties hinge on the presence of what is referred to as an infrastructure value, and on the need to separate this out from the final benefits received. This has meant that any valuation presented on the benefits from regulating services represents a marginal assessment (albeit a very large margin), rather than a total. Each regulating service and its associated benefits are discussed individually below, as each presents different issues for valuation.

The Typology of benefits arising from these services is presented in Table D.

Table D Typology of benefits from regulating services

(TEV = Total Economic Value; MV=market value; GVA = Gross Value Added; '-' = not applicable or not possible to identify for reasons stated in Section 4)

Service	Benefit	Sub-benefit	Constituent of TEV	Valuation Approach	Contribution to the economy
Climate regulation	Carbon sequestration	Reduced risks from climate change	Avoidance of a loss of welfare value (of various types)	Shadow Price of Carbon	-
Air quality regulation	Dry deposition of pollutants	Physical health protection	Avoidance of a loss of welfare value (health)	Avoidance of cost in health services, additional WTP for avoiding damaged health (Incomplete data)	-
Water purification & waste treatment	Clean water	-	-	Conceptual difficulties limit valuation possibilities	-
Natural hazard regulation & Water regulation	Flood protection	Protection of people, property and land	Avoidance of a loss of welfare value (of various types)	WTP meta-analysis	-
	Erosion control /Landslide and subsidence prevention/ Retention of soil for use		-	-	

Table E presents a summary of the benefits arising from regulating services. Each ecosystem service is discussed individually below.

Table E TEV of benefits provided by England's regulating services (£ million per annum)

Benefit	TEV	Notes
Carbon sequestration	1,007	Applies to benefits from woodlands and associated soils, wetlands and peatlands.
Air quality regulation	0.018-0.64	Annual health related benefits provided by England's woodlands from reductions in PM_{10} and SO_2.
Water purification and waste treatment	-	Due to the number of variables involved in the provision of water quality it was not possible to complete a valuation.
Flood protection	1.2	Flood control and storm buffering benefits provided by a subset of England's habitats

Climate Regulation

Climate regulation is provided by a series of interconnected processes and ecosystem services, such as water and air quality regulation, or supporting services (discussed below) such as water cycling, which all contribute to the provision of climate regulation services and resulting benefits. To avoid any overlap with other services and benefits, only those benefits from carbon regulation have been considered.
It is necessary to differentiate the carbon regulation services provided by stored carbon from those provided by carbon sequestration. This effectively points to the need to delineate carbon stocks from carbon flows. Only carbon flows (or sequestration) benefits are included in the assessment.

Both carbon sequestration and carbon storage benefits are highly dependant on the characteristics and condition of the habitats in question. This creates difficulties in assuming average sequestration rates.

Using an avoided damage cost approach, the annual value of carbon sequestration benefits provided by England's woodlands and associated soils are estimated to be just under £1 billion. This value dwarfs that provided by England's wetland (~£5 million a year) and peatland (~£5 million a year) habitats.

While it has not been possible to value the carbon sequestration benefits provided by all England's habitats, the estimates presented above are likely to represent the bulk of these benefits.

Air Quality Regulation

Ecosystems help to regulate air quality by assimilating the emissions to air of potentially polluting substances from human activities. However, ecosystem related effects are not the only natural processes at play in providing benefits related to air quality; oxidation, photochemical, and wind dispersal processes in operation in the atmosphere may play a significantly bigger role. This makes it difficult to specify the role of ecosystems in the provision of clean air.

The annual health related benefit provided by England's woodlands from reductions in PM_{10} and SO_2 is estimated to be between £18,000 and £645,000 per year. This represents a lower bound estimate as other benefits such as the damage avoided to buildings, and visual and aesthetic benefits are not included. Under a marginal assessment, the IGCB (Interdepartmental Group on Costs and Benefits, Defra) methodology for air quality damage avoided assessments would have been applied (Defra, 2007f). That methodology includes consideration of damage to buildings associated with air quality.

Water purification and Waste Treatment

In addition to the provision of water for drinking, water interacts with habitats and species in a number of other roles within ecosystems. Ecosystems provide water purification and waste treatment services, which result in the provision of clean or clearer water which then provides a series of important benefits, including health related benefits, visual and aesthetic benefits, and non-use benefits.

Certain habitats play a role in helping to purify water (such as reed beds and salt marshes) and in providing long term storage for both nutrients and contaminants. The ability of ecosystems to contain, dilute and breakdown substances that can build up in water and cause pollution issues provides a significant cost saving for society.

Due to the variables involved in the provision of water quality and waste treatment services across the country (e.g. pollution load, existing water quality,

land management activities), and the fact that benefits realised from these services are very site specific, it has not been possible to estimate the extent of the benefits provided regionally or nationally. This would require site specific assessment data of marginal changes.

Natural Hazard Regulation and Water Regulation

Natural environments and ecosystems provide natural hazard protection services in the form of controlling and managing the environment's response to certain weather conditions, and ultimately in buffering and mitigating impacts that may result from these and associated processes.

A number of conceptual issues arise when considering the benefits provided by these services. For instance, implicit in the consideration of these services is the fact that the benefits only occur following a natural hazard event or heavy rain fall and they are often dependent on land management practices. There is therefore a probabilistic element involved. Given the geographic scale considered here (i.e., national) and the associated variability in how benefits are realised, it is only feasible to consider the 'possible' benefits that might be provided by these services in a given year, rather than the 'actual' benefits that are realised by society, as is the case for some other services.

Using a benefits transfer of WTP values, it is estimated that the possible (as opposed to actual) flood control and storm buffering benefits provided by a subset of England's habitats (coastal & floodplain grazing marsh; coastal sand dunes; coastal vegetated shingle; mudflats; saline lagoons) are worth £1.2 billion a year.

This represents a partial valuation as it relates to the benefits provided by only a subset of the relevant habitat types, although these are the most significant habitat types to provide such benefits. It is therefore considered to represent a lower bound estimate of the full benefits provided nationally.

Given the large number of variables which interact to result in the provision of actual benefits (e.g., rain fall, land use, proximity to population centres) it was not feasible to estimate the actual benefits received in a given year, either regionally or nationally.

Cultural Services

The Millennium Ecosystem Assessment defines cultural services as those that provide the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences. This category therefore includes both direct non-consumptive uses (e.g. recreation) and non-use values (NUVs) (e.g. some aesthetic and cultural heritage aspects).

The baseline for considering the benefits from cultural services effectively assumes that the natural environment which remains under the baseline provides little to no cultural service benefits.

The Typology of benefits arising from these services is presented Table F.

Table F Typology of benefits from cultural services

(TEV = Total Economic Value; MV=market value; GVA = Gross Value Added; '-' = not applicable or not possible to identify)

Service	Benefit	Sub-benefit	Constituent of TEV	Valuation Approach	Contribution to the economy
Recreation Opportunities	Welfare benefits of participants Economic benefits of expenditure	Hill walking	CS & MV	Market data and stated preference WTP above cost	Income
		Casual walking/ Rambling			
		Freshwater Angling			
		Game shooting			
		Bird / wildlife watching	CS & MV (bird-watching only)		
		Cycling	CS	Stated preference WTP above cost	-
		Horse riding			
		Golf	-	Valuation not possible due to data limitations	
		Gardening			
		Watersports (includes canoeing, rowing, sailing, windsurfing)			
Knowledge Systems	Education	-	-	Valuation not possible due to conceptual problems	-
	Research				
Social Use Values	Local people gaining social use values	Social services, sense of place, spiritual, religious, continued traditional way of life etc.	-	Valuation not possible due to conceptual problems	-
Non-Use Values	Social/cultural heritage	Continue traditional ways of life; sense of place; spiritual; religious etc.	Non use	Marginal stated preference WTP	-
	Physical/land-scape/ built heritage	Landscape/aesthetics/built heritage etc			
	Biodiversity (habitats & species)	People-orientated intrinsic value			

A number of recreational activities are made possible by the presence of high quality natural environments and by the presence of wildlife (flora and fauna) within them. This assessment considers the ways in which ecosystems (through a variety of ecological processes) act to provide opportunities for people to undertake recreation e.g. the provision of a pleasant natural environment in which to go walking; or the provision of game for shooting.

Given the diversity of the benefits provided, valuation approaches applied vary by benefit. Benefits transfer has been applied to estimate recreational consumer surplus values, while market data has been used to estimate related expenditures. Income has been estimated from expenditure using a variety of multipliers.

The recreational consumer surplus generated from ecosystem services is at a minimum around £266 million per annum. Due to a lack of data, not all recreational activities have been valued, therefore this estimate represents a lower bound value. Expenditure values are estimated at £5,389 million per annum. The Total Economic Value estimate from recreation is therefore £5,655 million per annum. Income generated from recreational activities undertaken in England is estimated to be £1,1951 million per annum. See Table G for a breakdown of these values.

Table G CS and TEV for recreational activities (£ million per annum)

Activity	CS	Expenditure	**TEV**	**Income**
Walking	£65	£3,093	£3,158	£742
Freshwater angling	£93	£1,164	£1,257	£997
Bird watching	£16	£34	£50	£8
Game shooting	-	£1,098	1,098	£204
Cycling	£19	-*	19	-*
Horse riding	£73	-*	73	-*
Golf	-*	-*	-	-*
Gardening	-*	-*	-	-*
Watersports	-*	-*	-	-*
Total	£266	5,389	**5,655**	**1,951**

*Note: *gaps in available data limit valuation of benefits*

The valuation presented here can be considered to underestimate the total value of these activities in England due to a number of gaps in the valuations. The key limitation is in identifying appropriate willingness-to-pay and /or expenditure values. It is also important to note that each recreational activity has a different degree of reliance upon healthy natural ecosystems which should be considered when assessing the role of ecosystems in the provision of the benefits.

The Millennium Ecosystem Assessment identifies knowledge systems as a service within the cultural services category. This service can be seen to provide both education and research benefits that are obtained from working with and learning from natural ecosystems.

Social use values are obtained from the benefits people get by living around and working with ecosystem services (e.g. traditional reed cutters and salmon netsmen). These people are likely to gain an additional benefit not associated with recreation or the products they obtain. The benefits will be more akin to the people having a sense of place, some spiritual or religious benefit, social services, and a continuation of a traditional way of life.

It was not possible to quantify and value the benefits arising from knowledge systems and social use values. While it is clear that these services provide significant benefits to society, conceptual difficulties in identifying the nature of the final benefits realised limit valuation.

Non-use values are benefits perceived by individuals that are not associated with the actual use of, or even an option to use, the ecosystem or its services. Non-use values are therefore a 'special case' in that they are not dependent upon any particular ecosystem service as such, but simply upon the existence of species,

habitats, landscapes, or social and cultural heritage. Therefore identifying the role the ecosystems play in the provision of these values is not straightforward.

When it comes to benefits arising from non-use values, conceptual difficulties in identifying the extent of the benefits abound, given the objective of estimating the value of the total benefits. Presented by way of illustration is a rough minimum estimate of £399 million per annum. This value is based on a marginal assessment and therefore should not be considered comparable with some of the other benefit values presented here. Care is required when interpreting this figure.

Supporting Services

Supporting services can be defined as the services that are necessary for the production of all other ecosystem services. They include services such as: microclimate regulation; nutrient cycling; photosynthesis; pollination; primary production; soil formation and functioning; and water cycling. It can therefore be argued that the value of supporting services is infinite, as without them there would be no other services or final benefits. These services provide an 'infrastructure' service that is necessary in some way to realise all of the final benefits.

For these reasons supporting services are not included within the overall typology presented. This does not mean that supporting services should not be considered as part of an overall ecosystems approach, nor should it be taken to suggest that the benefits accrued by these services have no value to society. A case study presents specific consideration of the benefits provided by pollination, considered here to be a supporting service. This is discussed further under the Case Studies section below.

Aggregation and disaggregation of benefit estimates

The study explores the issues around three different types of aggregation – aggregation across different geographical scales, aggregation of benefits derived from different valuation approaches, and aggregation of marginal to total value estimates. These are discussed below.

1. Aggregation across different geographic scales e.g. aggregating regional results to a national level, or conversely disaggregating national data to a regional scale;

The overriding consideration for aggregation, especially in cases of marginal change assessments, is whether it is appropriate to assume that the value estimated for one location is applicable to the preferences of people in another, and whether it is legitimate to apply a site specific value more generally without taking into consideration the characteristics of individual sites and substitute sites.

The method of valuation obviously impacts on the significance of this consideration. If stated preference or revealed preference methods are used to estimate willingness-to-pay then individuals' preferences will play a significant role in overall value. However, if market price approaches are applied to value the benefits, variations in regional preferences are less likely to be of concern.

2. Aggregating the value of different types of benefits measured by a variety of valuation approaches;

Aggregation in this context refers to the summing together of benefit estimates derived by different valuation approaches. The valuation approaches used have generated a range of monetary indicators and care is required in how these are summed together to generate an overall value estimate. It is necessary to ensure that the indicators represent similar components of welfare and that double counting does not occur.
As noted above, Total Economic Value is equal to market value (or expenditure) plus the consumer surplus value. Therefore the value of these individual types of benefits can be summed to estimate an aggregated Total Economic Value. Where the valuation estimates a total WTP based on a proxy value, for instance damage cost avoided, this is taken to represent the total willingness-to-pay value of this benefit, and therefore is equal to Total Economic Value. This value can not be summed with the market value or consumer surplus for a given benefit, as that would represent double counting.

GVA and income estimates are presented to reflect the contribution to the economy made by ecosystems. They can not be added to market value or consumer surplus values, as they do not form part of the Total Economic Value.

3. Aggregation from marginal to total value estimates;

A review of the literature demonstrates that existing values for ecosystems are typically based on marginal analyses of changes, under the assumption that all other things are equal. Diminishing marginal utility for the scale of an ecosystem implies that, as the scale of an ecosystem diminishes, so the value of the remaining ecosystem increases. The same is assumed for the flow of benefits from that ecosystem. However, this may not apply in all cases.

Economic theory also states that the value of any set of goods depends on the path or sequence by which they are valued and aggregated. This is the path dependency problem which arises because of substitution and also income effects between goods.

Therefore the WTP for 'all ecosystems' is likely to be significantly higher than the sum of the WTP estimates for each individual benefit from ES assessed separately.

It cannot simply be assumed that values which have been estimated for 'small' changes in ecosystem services can be used for valuing (in effect) far larger 'changes'.

Gap Analysis

The study uses a mix of valuation approaches to estimate the TEV and the economic impact of the benefits provided by England's ecosystem services. However, it has not been possible to value all benefits identified. This is for a number of reasons and not solely as a result of missing valuation data.

It should be noted that the significance of the gaps identified for further valuation work will vary depending on the specific nature of the valuation tasks and the key policy areas that Defra feels are important in this context.

That said, without a clear understanding of the biophysical relationships at play within ecosystems, valuations that can be completed will always contain unknown margins of error. The implications of these errors will vary depending on the type of decisions which they are being used to inform.

Details are provided in the main report on the nature of the gaps and how these have affected the completion of a valuation for each specific benefit. It can be seen that these gaps can be classified as follows:

1. *A gap in our understanding of the biophysical relationships between aspects of the ecosystem and how final benefits are realised*
   For this study, this gap hinges mainly on the difficulties of defining a clear baseline from which benefits can be identified. It also relates to the geographic scale at which the assessment is being completed, as the ability to specify the benefits reduces as the geographic scale and the number of variables involved increases. This gap concerns how to describe and quantify the role ecosystems play in the provision of services and benefits. Valuation of the benefits received from water purification services was limited by this type of gap, as it was not possible to identify the extent of the benefits over the baseline.

2. *A gap in the data available to quantify the benefit*
   In some cases, where it has been possible to identify how a benefit is generated, it has not been possible to locate data on the extent of that benefit at a regional or national scale. Such data is necessary to attempt to quantify the ecosystem service benefits. This gap was encountered, for instance, with the valuation of some recreational benefits, and benefits received from the provision of wild produce.

3. *A gap in the data available on the monetary value of a given benefit*
   This gap may relate to market value, consumer surplus value, or total willingness-to-pay estimated via a variety of approaches, and relates to the ability to identify the appropriate monetary value for the benefit. This type of gap was only encountered in a few cases, however as noted in the conclusions, the appropriateness of some of the valuation data applied here for policy decision making may be questionable.

Case Studies

A number of case studies have been completed in order to investigate specific issues.

A growing body of evidence highlights that ecosystems play an important and valuable role in sustaining and promoting **physical and psychological health** in people and communities. These benefits are 'cross cutting' in that they are provided by a suite of ES, either individually or in combination. This case study presents an overview of the direct and indirect health benefits provided by ecosystems, in order to clarify the range of health benefits which might be provided by a given policy.

The key points coming from this case study are:

- Physical and mental health benefits derived from ES are not identified within the Services and Benefits Typology (see Section 3.6) because they are considered to be cross–cutting and provided by a range of ES. They are typically realised through the complex interaction of a number ES.

- Ecosystems provide direct health benefits through the provision of food, medicines and materials. It is estimated that 50% of prescription drugs are derived from natural compounds. Benefits in relation to the provision of fuel for heating are also provided.

- Indirect benefits are provided by key ecosystem services, such as the absorption of atmospheric pollutants and the provision of opportunities for physical activity which promotes health and well-being, physical and mental. Biomass has the potential to provide considerable amounts of renewable energy, potentially replacing non-renewable sources and providing health benefits associated with reduced air emissions.

- The valuation of ecosystem related health benefits is a complex task, intensified by the presence of multiple benefits from a single service (creating a risk of double-counting), and in some cases by the subjective nature of the benefits.

Pollination is categorised in this research as a supporting service. The objective of this case study is to present a discussion on the nature of the benefits provided by this ES and on the valuation literature, and to note some of the issues around valuing these benefits.

The key points from this assessment are:

- Pollination is an extremely valuable yet often under-appreciated ecosystem service. Pollination generates value for society by supporting other ecosystems (agricultural and non-agricultural), which in turn generate benefits through enhanced productivity. As a supporting service, the benefits of pollination services must be considered within the context of other ecosystem benefits (e.g. food production, recreation, non-use value).

- A relatively large number of studies, including some from the UK, have attempted to put a monetary value on the benefits arising from pollination in terms of crop productivity. Estimates show that the value of pollination services is far higher than the value of honey production.

- In contrast, there appears to be little evidence of research into non-market benefits provided by pollination, yet these are likely to be major components of the total value of this service.

- Wildflowers are a vital component of many of the UK's most valued landscapes and some 90% of their species are thought to be critically dependent on pollinators. To protect landscape and biological diversity, it is therefore essential to protect pollinators.

- Importantly, pollinators themselves are critically dependent on the integrity of ecosystems (e.g. to provide opportunities for foraging, nesting and reproduction). Pollinator populations are declining; there has been a nearly 50% decrease in bee colonies since the 1950's. Therefore evidence is growing for the need for improved policies to encourage landscape/habitat diversity in support of pollinators.

The third and fourth case studies present actual valuation examples.

Many ecosystems are made up of numerous habitats, each providing a number of different services. Policy can incentivise change from one habitat to another,

for example, a policy may result in grassland or intensively grazed land being planted with trees to restore woodland or to address a flooding issue.

In the UK flooding is common and often results in significant damage to land, people and properties, generating financial and economic costs. The nature of the habitats in a floodplain can have a considerable impact on the extent and timing of the damage due to flooding.

A marginal valuation of a range of benefits that might be generated as a result of a **land use change (arable to wet woodland)** is presented. The objective here is to illustrate to decision makers the full range of benefits which might be provided from a particular policy driver, in this case flood protection. While the assessment presented is marginal, it is not a net assessment.

The key points from this case study are:

- Policy-driven land use changes can have broad impacts. Flooding in the England is an increasingly important issue following the floods of summer 2007, and ongoing research is exploring alternative protection options to hard defences.

- Creating floodplain woodlands by land use change is one protective option under investigation. Research is showing that the flood protection and prevention benefits of floodplain woodlands can be large and are likely to outweigh the opportunity cost of losing alternative land uses.

- It is clear that while the driver for land use change in this case is flood protection, additional benefits can be realised. In order to maximise these additional benefits, they need to be recognised at the policy development stage and incorporated into the decision making process.

- In the case study the benefits include biodiversity, carbon sequestration, nutrient cycling, recreation, and non-use. While the net benefits of a land use change from grassland to floodplain woodland are large and in some cases easy to describe qualitatively, they can be difficult to quantify and thus, to value.

- An increase of 50 hectares of floodplain woodland is estimated here (using hypothetical data) to bring benefits worth around £126K to £266K per annum. This is considered to be a lower bound estimate.

The benefits of ES are by no means restricted to natural or semi-natural settings. The advantages of green spaces in the urban environment are well documented (e.g. in terms of physical and mental health, carbon sequestration, noise reduction, assimilation of soil contamination). Another important consideration is the **benefit that urban trees provide in terms of air quality.**

The final case study examines how health related benefits are provided by urban trees in two London boroughs, and values these benefits based on a damage costs avoided approach. A discussion of other benefits provided by urban trees is also provided here.

This assessment represents a total valuation (i.e. a valuation of the benefits currently provided by these urban trees). However, the damage costs values can also be applied in marginal assessment.

The key points coming from this are:

- Ecosystem services are not restricted to natural or semi-natural locations; green spaces, specifically trees, in an urban environment provide numerous benefits. Direct and indirect benefits arise from the effect on air quality (gaseous and particulate), temperature, and the aesthetics of an area.

- Using complex air quality, emission and transpiration modelling, it is possible to infer the following:

    - *Mature, mixed woodland sequesters airborne particulates at three times the rate of grassland;*

    - *Trees at the edge of woodland are more efficient at sequestering particulates than those in the centre; and*

    - *Evergreens are more efficient than deciduous trees at providing pollution removal benefits.*

- To value the benefits provided by urban trees, damage cost values are applied. These are estimated for each pollutant based on avoided deaths brought forward and avoided hospital admissions. PM_{10} has the greatest damage cost per tonne per annum, therefore the greatest benefit arises from its removal.

- A conservative central estimation of the health benefits of pollutant removal by urban trees in two London Boroughs is approximately £22K and £67K.