Natural England Research Report NERR033

Microeconomic Evidence for the Benefits of Investment in the Environment - review

www.naturalengland.org.uk

NATURAL ENGLAND

Natural England Research Report NERR033

Microeconomic Evidence for the Benefits of Investment in the Environment - review

Tim Sunderland

Published on 01 March 2012

ISSN 1754-1956

Project details

A summary of the findings covered by this report, as well as Natural England's views on this research, can be found within Natural England Research Information Note RIN033 – Microeconomic Evidence for the Benefits of Investment in the Environment - review.

This report should be cited as:

SUNDERLAND, T. 2012. Microeconomic Evidence for the Benefits of Investment in the Environment - review. *Natural England Research Reports, Number 033*.

Project manager

Tim Sunderland
Natural England
Temple Quay House
2 The Square
Bristol
BS1 6EB
Tel: 0300 060 4638
tim.sunderland@naturalengland.org.uk

Acknowledgements

The author gratefully acknowledges the help of many internal reviewers. This evidence package has also been peer-reviewed by the following Natural England staff:

Specialist Group

- Harlow, Julian - Principal Specialist Economics
- Brotherton, Pete - Principal Specialist Biodiversity
- Hopkins, John - Principal Specialist Ecosystem Services (up to March ’11)
- Waters, Ruth - Principal Specialist Ecosystem Services (from April ’11)
- Burn, Alistair - Principal Specialist Freshwater and Pollution
- Collins, Tim - Principal Specialist Water and Coastal Issues
- Morecroft, Mike - Principal Specialist Climate Change
- Macgregor, Nicholas - Principal Specialist in Landscape Scale Conservation
- Stone, Dave - Principal Specialist Health and Access
- Alexander, Ian - Team Leader Landscape Scale Delivery Southern England (about organics)
- Cathcart, Rob - Senior Specialist in Freshwater and Wetlands
- Wetherell, Anna - Senior Specialist, Hydrology and Hydrogeology
- Shepherd, David - Senior Specialist, Invertebrate ecologist
- Clarke, Stewart - Programme manager, Ecosystem Approach and Climate Change

User Group

- Schüder, Ingo - Senior Adviser, Green Infrastructure
- Davies, Fran - Senior Adviser, Land Use in Kent (until March ’11)
- Ward, Helen - Lead Adviser, Statutory Land Use Consultations

Summary

MEBIE – the Micro-Economic Benefits of Investment in the Environment Review is an in-house literature review. It is focussed around 'green infrastructure' interventions and is structured using the Ecosystem Approach. It is designed to help Natural England staff make the case for the natural environment to decision makers such as Local Authorities and Local Enterprise Partnerships. It is structured to be easily accessible to staff, with benefits presented both in terms of major economic themes and in terms of individual ecosystem services. Each section provides a critical review of the literature, which informs staff whether, and under what circumstances, the proposed benefits of investment in the Natural Environment exist. This is followed by examples. Where there are monetised studies these are offered, but where there are none more qualitative examples are offered. Case studies are written up in pithy bullet points, designed to make the case as effectively as possible whilst being true to the evidence base. Background to the examples is offered in footnotes, so that staff can understand where the evidence they are presenting has come from.

Contents

Appendices

How to use this review

1a: About the review

What is this review for?

1.1 It is designed to help Natural England staff make the case for the natural environment to decision makers such as Local Authorities and Local Economic Partnerships.

What is its orientation and scope?

1.2 The natural environment offers many benefits which are often taken for granted, until they are lost or damaged. Furthermore, deliberate investment in the natural environment can produce benefits in ways which may not be considered in economic planning. These can often represent better value for money than more technological solutions. This review provides evidence which will help decision-makers take account of the benefits of the environment. However, no claim is made to cover this area exhaustively and it is hoped that future additions will add to the evidence base offered. The review offers economic evidence which is relevant to the green infrastructure (GI) agenda, which focuses on land use planning in order to optimise these environmental benefits.

How the review can help

1.3 This package provides evidence about the economic benefits of environment in an accessible format. It highlights potential benefits, reviews the evidence for them and gives references to support the case. It also highlights contextual limitations and uncertainties. Where case studies and/or economic values exist to support a case, these are provided in bullet point summary form, along with a review providing the background to the headline figures. A methodology section is provided in the appendix to provide transparency as to the depth to which the review has been undertaken. Chapter 2 provides short essays which are a 'short-cut' to finding evidence relevant to important economic themes.

What the review cannot do

1.4 The evidence package can demonstrate the weight of evidence around a particular benefit. It can also point to relevant case studies that are useful in making the case. However, it cannot provide a formula which allows the production of values which relate to the project that you are advocating for. In many cases, explaining the argument based on the logic-chain evidence and case studies may be sufficient, but if you need specific numbers speak to the Natural England economics team for further advice. It may be possible to undertake a value transfer, in which values are inferred from similar cases, but the economics team will advise you whether this is appropriate and how meaningful the resulting figures are likely to be. Where this is not appropriate a bespoke study would be necessary, but this may cost £250K, which is unlikely to be justified in most cases.

Why you need to read the rest of this chapter

1.5 The evidence package is designed so that the contents page takes you rapidly to the evidence and case study facts you are looking for. However, you will be able to use it much faster and much more effectively if you understand how its structure works. Section 1b therefore provides an essential orientation to the document. A brief introduction to economic evidence is necessary and this is provided in 1c.

Feedback

1.6 I am keen to receive feedback on this review, to make improvements ahead of a potential version 2. I can be contacted at **tim.sunderland@naturalengland.org.uk**.

1b: How to use the review

1.7 This section provides an orientation to the structure of the review, which is designed to be used as a reference document, rather than read from cover to cover.

How to find what you are looking for

1.8 If you know what sort of evidence you are looking for, scanning the contents pages should allow you to quickly locate it. However, if you don't, turn to Chapter 2 which provides short essays on key themes with links to the relevant evidence. Chapter 3 provides evidence about traditional economic concerns. This evidence draws on a much broader suite of evidence about ecosystem services which is presented in Chapter 4, using a methodology adapted from DEFRA (2007b).

Section structure

1.9 Chapter 2 takes the form of thematic essays, but the sections in chapters 3 and 4 are divided into sections presenting a particular benefit. Sections vary according to the needs of the evidence presented, but sections look like this:

Introduction

This section will explain the benefit under discussion, what is included and excluded and how it fits into economic theory. It will also provide links to related benefits.

Logic chain

This subsection will present the **proposed** benefit to people from a change in the environment in terms of a logic chain (stylized examples given below). Some times a simple proposition will be offered instead. The evidence for or against the proposed benefit or logic chain will then be assessed in the sections below.

Figure 1

(The provisioning services section follows a different structure. A production chain is offered, not to test, but as background, and then evidence for threats and opportunities is offered.)

Can the benefit be quantified?

1.10 This subsection will consider whether it is possible to appropriately quantify the relationships in the logic chain, and the barriers to doing so. This provides essential context 'how strong is the evidence?' subsection, because the strength of the evidence needs to be considered relative to the field of knowledge it is in. For example strong evidence for causal links is much more difficult to achieve in the social sciences, than in the natural sciences.

How strong is the evidence?

1.11 This subsection will review the relevant literature and provide an assessment of the strength of the evidence connecting the logic chain, including any significant uncertainties and contextual factors.

Connections with climate change

1.12 Where the case for the benefit is strongly related to climate change this section will explain the link and offer any relevant facts. Climate change has been singled out as a priority because it is one of the most significant sustainability challenges of the 21st century and therefore receives a great deal of attention from **economic** as well as environmental policy. Additionally many green infrastructure interventions have the potential to contribute to climate in terms of mitigation, adaptation or both.

Examples and figures

1.13 This section will contain any case studies which can be used to support the case for a particular benefit. Robust quantitative and qualitative evidence will be presented. The wording of these bullet points has been chosen carefully to make the case for green infrastructure whilst representing the research accurately. I therefore recommend quoting them verbatim if you are not going to read the original article. The footnotes in the section are very important because they provide the background details about the study which give context to the figures and conclusions presented, and any concerns or contextual limitations about the study. **Reading these is essential to provide you with the confidence to respond to any challenge to the figures your are presenting.**

1c: Introduction to economic evidence

Purpose of this section

1.14 This evidence package is designed to help you make robust, evidence based arguments for the benefits offered by the natural environment, demonstrating that investment in the environment represents a rational use of limited funds. In order to do so however there are some economic terms and approaches you need to understand. This section provides a 'bare-minimum' account of these terms.

Counterfactual or baseline

1.15 All the economic evidence in this package refers to the benefits derived from an **improvement** in the natural environment, or the loss caused by **damage** to the natural environment. That is to say it's all about a **change** in the environment. For example, you can't put a value on Dartmoor, but you can value the difference in the benefits of freshwater from Dartmoor under two different management scenarios (for example, increasing Dartmoor's woodland cover by x%). What we value is the project, not Dartmoor itself! This means that evidence is based on the difference between what happens because of the project and what would have happened anyway, which is known as the counterfactual or baseline position.

Impact and value

1.16 When dealing with economic evidence, it's very important to understand that numbers which refer to economic benefits can refer to two very different things - economic **impact** (the effect on GDP, whether positive or negative) and economic **value** (the total affect on the welfare of the individual whether caused by changes to consumption of traded goods, or more intangible things such as the beauty of a landscape). In environmental economics values are placed on these intangibles either asking people how much they would be willing to pay for them in a hypothetical market[1] or through observing market behavior related to their value (for example are house prices higher near an attractive park)[2]. The economic value approach forms the basis of Cost Benefit Analysis, which is the UK's dominant decision making framework (HM Treasury, 2003). The distinction between **impact** and **value** is very important so when quoting a figure from the evidence package be sure that you understand which it refers to.

Double-counting

1.17 When presenting economic evidence it is essential to avoid counting the same benefit twice, otherwise you undermine the credibility of your evidence base. For example, evidence about how much being near a park increases houses prices is likely to be based on the aesthetic benefits of the park and so these should not both be counted. Because of this, particular care should be taken when combining evidence from chapters 3 and 4.

Timeframe

1.18 When quoting numbers, it's very important to be clear about the timeframe for the numbers you're quoting. For example, is a benefit of £1million a one-off benefit, or is it likely to recur? And, if so, how long can it be expected to recur on the basis of the investment under consideration?

Cost benefit analysis

1.19 This is a decision-making tool which the government uses to assess whether a proposed project represents good value for public money. Once a project is identified, all the relevant costs and benefits associated with that project are considered. One complication of this analysis is that all the costs benefits may not occur in year one, so you need a method of comparing the value of 'year one' costs or benefits with those in the future. Discounting reduces the value of a future cost or benefit by a fixed percentage for each year it is into the future (the discount rate). The UK's official social discount rate is 3.5%[3]. So if for example if we were expecting to receive a benefit of £1000 in ten years time that value is reduced by a compound 3.5% for each year (like compound interest in reverse), leading to a figure of £700.28[4]. This figure is known as the Present Value (PV). The table below shows how the PV of a future benefit falls as it moves further away from the present.

Table 1

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Value	1000	965.00	931.23	898.63	867.18	836.83	807.54	779.28	752.00	725.68	700.28

1.20 Discounting like this means that benefits which are more than 25 years away are not worth considering and therefore 25 years is a standard time span for a cost-benefit analysis[5].

1.21 The final outcome of a CBA is offered as a benefit: cost ratio. For example a benefit: cost ratio of 5:1 suggests that the project will yield benefits five times the cost impact. A major problem with environmental CBA is that many of the benefits are subject to a high degree of uncertainty and therefore are often not placed into the benefit: cost ratio. This marginalises them from decision making. It is therefore important to push for the full range of costs and benefits be considered, even where there is significant uncertainty in quantification.

About environmental justice

1.22 There is good evidence that environmental 'goods' and 'bads' are unequally distributed through society, with the poorest suffering from more of the 'bads' and benefitting from less of the 'goods' (Environment Agency, 2008b, NAO., 2006). This is due to both the effect of the housing market and central and local government planning decisions. An unadjusted CBA will show that this distribution is the most appropriate outcome[6], but Treasury guidelines allow for inequality to be adjusted for (HM Treasury, 2003). In policy terms environmental injustice might be an important motivating factor for a Green Infrastructure intervention. For example, improved greenspace in a deprived part of the inner-city might lead to a better health improvement than in a wealthy area which was already well endowed with greenspace. This means that for some of the Green Infrastructure interventions discussed knowing exactly as possible who the beneficiaries are is important.

Context for large numbers

1.23 Environmental benefits are often significant, and therefore involve large numbers. Some audiences may lack of context for large numbers, and some are offered for context below:

- Total UK Government spending in 2008/2009 = £621 billion;
- DEFRA budget over same period = £3.1 billion;
- Bristol City Council budget = £400 million annually; and
- A five bedroom house in a sought after district of North Bristol = £500,000.

---

[1] Known as the contingent valuation method.
[2] Known as the hedonic pricing method.
[3] The social discount rate represents the Treasury's view of the discount rate from the point of society as a whole. It differs from private sector discount rates which may be much higher and is published in the Green Book.
[4] Formulaically this is (1000*(100-3.5)) 10 = 700.28.
[5] There is considerable controversy about the discount rate, in particular whether such a short term focus is appropriate for making decisions with regard to the environment. The UK Green Book includes separate guidance for long-term projects which partially address these concerns.
[6] This is because an unadjusted CBA assigns 'votes' to pounds not people, and so wealthy people's preferences count more than poor people's preferences. The Green Book encourages and allows for distributional affects of projects to be considered, but this is in practice relatively uncommon.

2 Relating evidence to significant themes

Economic growth and regeneration

Introduction

2.1 There is a great deal of interest in the way in which green infrastructure contributes to economic growth. This section pulls together findings from the rest of the package to make this case.

Health and productivity

2.2 There is good evidence linking access to, and views of greenspace to improved physical and mental health outcomes (see 4a: **Health and society**). Logically this should lead to improved productivity and reduced worker absence. Additionally, there is suggestive evidence of a more immediate relationship between views of plants and nature and productivity (see **labour productivity**).

Image and attractiveness

2.3 There is good evidence that green infrastructure contributes to the attractiveness of a local area and suggestive evidence that there may be broader settlement or county effects. This may help to attract mobile businesses and people to your area (see the first four sections of **economic competitiveness** for evidence of impact on economic indicators). Also see **local climate regulation**, **air quality** and **noise**, for the non-aesthetic ways green infrastructure can make areas more attractive).

Tourism and recreation

2.4 An attractive natural environment and urban green infrastructure is a significant attractor of tourist and recreation expenditure (see **tourism and recreation**).

Community cohesion

2.5 There is evidence which suggests that green infrastructure may make a contribution to social cohesion, which in turn makes a contribution to economic and social dynamism. See **community cohesion**.

Essential context

2.6 The points above highlight some of the ways in which green infrastructure may contribute to economic growth, and focuses on psychological and social factors. This is only a small part of the economy's dependency on the environment. The economy's most significant dependencies are for limited natural resources (ie, wood, coal, fish) the environment's limited capacity to absorb the wastes the economy produces without harm (ie, climate change and eutrophication). Neither does the evidence given in this package address the issue of the effect of the economy's growth on the environment. To get this section in context it is essential to also read the **economic security**, **climate change mitigation** and **climate change adaptation** sections.

Economic security

Introduction

2.7 Economic security is not as widely discussed as economic growth, but at least as important. Economic security is about planning to ensure that the economy is resilient in the face of potential shocks which could significantly undermine it. As environmental challenges grow, so does the strength and depth of the relationships between them. This greatly increases the risk of systemic collapse of environmental services which are essential to the economy (European Environment Agency, 2010). For this reason holistic economy/environment management is increasingly necessary.

Water, food and resources

2.8 Climate change is set to make freshwater availability a major pinch point for the South East (see **freshwater**). There are significant potential threats to food security from soil exhaustion and scarcity of fossil fuels (see **food**).

Flooding

2.9 Economic activity has already increased flood risk and climate change will intensify this. But Green Infrastructure can help (see **Flood control - freshwater** and **Flood risk management at the coast**).

Heat and air pollution

2.10 Urban centres in particular may in future suffer from dangerous heat and air pollution. But Green Infrastructure can help (see **Local climate regulation** and **Air-quality**).

Health

2.11 Poor mental and physical health is already a major brake on economic activity for some communities, and problems such as inactivity and obesity are predicted to get worse. Green Infrastructure should be part of a holistic response to these issues (see **Health and Society**).

Climate change mitigation

Introduction

2.12 Climate change is the biggest long-term security threat to the economy. Current cuts in carbon emissions are far from sufficient to keep average global temperature increase below 2 degrees, pointing to the need for increased effort in mitigation and adaptation (European Environment Agency, 2010). Additionally Local Authorities are now expected to plan to both grow their economy and reduce their carbon footprint at the same time. Measures to mitigate climate change therefore should take a place of priority in economic planning.

Carbon sequestration

2.13 Land use change can reduce or increase the rate of carbon emission, as well as sequester carbon. Deliberate investment in the carbon sink function of land is therefore a priority for climate change mitigation (see **Carbon sequestration**).

Avoidance of energy use

2.14 Meeting low carbon targets will require significantly increased energy efficiency. Green Infrastructure can reduce the need for heating and cooling of buildings (**Local climate regulation**). Using Green Infrastructure solutions can deliver many essential services at lower energy cost (**Food**, **Freshwater**, **Flood control - fresh water**, **Flood risk management at the coast**, **Water purification and treatment**).

Behaviour change

2.15 Meeting carbon targets is likely to require significant behaviour change, particularly with regard to active travel (see **Increased likelihood of physical activity**).

Climate change adaptation

Introduction

2.16 Research shows that we are already locked into a significant degree of climate change. Current cuts in carbon emissions are far from sufficient to keep average global temperature increase below 2 degrees, pointing to the need for increased effort in mitigation and adaptation (European Environment Agency, 2010). In fact the temperature in central England has already risen by about 1 degree since the 1970s[7] (DEFRA, 2009) and the sea surface temperature has risen by 0.7 degrees in the last thirty years (DEFRA, 2009). Therefore an essential part of economic planning is to adapt to the climate change we are already committed to. The best adaptations will also contribute to mitigation.

Water

2.17 Climate change will drive decreasing availability of freshwater, particularly in the summer and in the South East (see **Freshwater**). Problems with polluted agricultural runoff are also expected to increase with climate change (see **Water purification and treatment**).

Flooding

2.18 Climate change is likely to increase the severity and frequency of flooding (see **Flood control - freshwater** and **Flood risk management at the coast**).

Urban heat island

2.19 There is a significant risk that urban centres may become unliveable due to the interaction between increased heat and air-pollution (**Local climate regulation** and **Air-quality**).

---

[7] This estimate if from DEFRA's climate change adaptation projections, which are based on consideration of the world's best climate models. They use a baseline of 1961 - 1990 meaning that some of this change has already occurred. This figure is based on central estimate, which is effectively business as usual with regard to global carbon emissions. It serves as an example of information available from other regions from **http://ukcp09.defra.gov.uk**.

Value for money

2.20 Green Infrastructure is designed to get the most benefit out of what nature is doing for free, which reduces the amount which needs to be done by expensive technology and hard infrastructure. Therefore there are many examples where green infrastructure offers much better value for public investment than the alternative.

2.21 For example natural water filtration is much cheaper than the alternative (see **Water purification and treatment**), natural flood defence even more so (**Flood control - freshwater**, **Flood risk management at the coast**). Natural climate control is much cheaper than the air-conditioning (or heating) it replaces (see **Local climate regulation**). Finally natural air filtering is likely to be efficient compared to technical alternatives, particularly as trees provide so many other benefits (**Air-quality**).

2.22 Mental and physical ill-health impose enormous costs on area and businesses. Access to greenspace and the promotion of active travel are extremely cost-effective ways to address these problems (**Health and Society**).

3 Economic competitiveness

3.1 Much of the evidence offered about the economic competitiveness advantages of the natural environment/green infrastructure is based on holistic impact, rather than specific ecosystem service. Arguments are sometimes advanced which are too vague to martial any economic evidence around. In particular the **scale** at which the benefits operate is often insufficiently clear. In order to offer economic evidence there needs to be a benefit, which people value enough, that they would be willing to do without something else, in order to receive it. With this in mind, this section is organized around evidence which would allow us to discern a benefit in this way:

- **House prices - proximity effects**
  This section covers domestic property price increase due to attractive views of the natural environment or park space and due to close proximity to accessible greenspace. In economic terms this is an effective method of discerning the value people place on these public goods.
- **House prices - settlement and regional effects**
  As well as these street by street effects there is also discussion of more general beneficial effects of perceptions of an area or settlement, often discussed under the term **quality of place**. Just about the only way to assess such a claim in economic terms is more generalized effects on house prices.
- **Inward investment - proximity effects**
  There is some literature which suggests that businesses prefer to use commercial property which has views of, or access to attractive greenspace, effectively the 'view from the office window'. If this is the case it should increase **commercial property prices** where these characteristics are present, and the availability of office space with these characteristics should support inward investment.
- **Inward investment - settlement and regional effects**
  As well as the 'view from the office window effect' there is also discussion about more generalized settlement and regional effects of environmental quality. Evidence here might relate to flows of inward investment as well as **commercial property prices**.
- **Tourism and recreation**
  There is a great deal of literature highlighting the importance of the environment to promoting tourism and recreation. This section considers this evidence, teasing out how much of this economic activity is dependent on landscape or biodiversity.
- **Labour productivity**
  This section reviews the evidence that the presence of greenery in the office, the 'view from the office window', or greenspace in office grounds can improve labour productivity.

House prices - proximity effects

Introduction

3.2 People value both proximity to, and views of, greenspace[8]. For this reason they may be willing to spend more on properties that afford them this benefit, and the evidence for this is reviewed in this section. However, before presenting the evidence it is helpful to position it clearly in economic theory. Whereas an investment in a new technology can increase the efficiency with which goods are produced and therefore increase the size of the economy, property is not a productive asset. This means that property price increases are **not an economic benefit** in themselves. Increases in property prices merely transfer wealth from those buying property to those selling it. Therefore increasing property prices does not make sense as a goal of economic policy. Another way to look at this is to say that the budget people have for buying houses is limited by their income and available credit. Improvements in a local park will not therefore pull more money into the house purchasing budget, but simply redistribute it around a town or city. It is a **relative** not **absolute** change in property price. This means that the argument that parks can pay for themselves through increasing the price of property nearby (Crompton, 2005) is fundamentally wrongheaded (this is unless the environmental quality in a city in general terms increases its competitiveness, which is dealt with in the next **section**). There are however two reasons why increasing house prices might be good news. Firstly, it might be an **indicator** of increasing strength in the local economy (alternatively it might be part of a boom driven by unsustainable credit!) Secondly, if your concern is about the regeneration of a deprived area, rather than economic growth per se, you will be pleased that increasing prices show a relative improvement of your target area, relative to other localities. Improvements in property prices may be welcomed by Local Authorities as they increase the tax base (possibly unsustainably) and by developers if they improve the retail price of their units.

3.3 This means that rather than a focus on economic **IMPACT**, property prices are of most interest as an indicator of economic **VALUE**[9]. The fact that people are willing to pay more for properties with a view of, or close to, greenspace is important evidence that they value it. This evidence might even have the potential to shed light on which greenspaces people value most. It is difficult to be entirely sure which of the many benefits of greenspace are captured by property prices, but it is likely that it is predominantly aesthetic and recreation benefits, as opposed to less obvious things such as flood control.

Logic chain

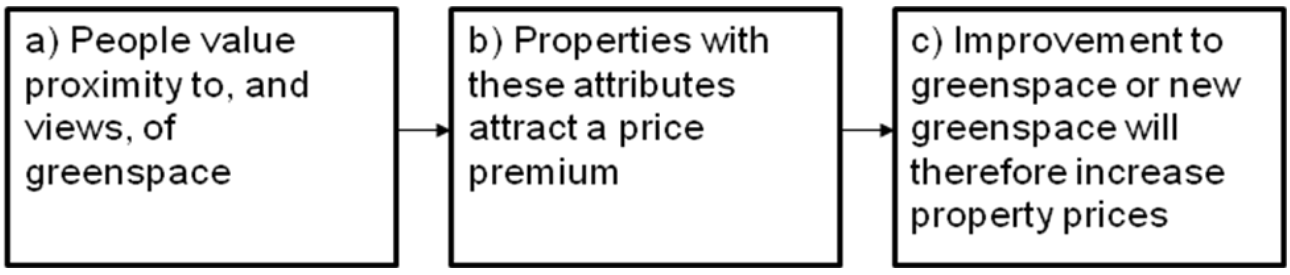

Figure 2

Can the benefit be quantified?

3.4 Useful quasi-experimental attempts to value the relationship between property prices and greenspace in any given moment have been carried out, but they can never be sure they have been able to control for relevant confounding factors. However, when it comes to the relationship between house prices and greenspace over a time period, the number of factors to control for increases exponentially. Therefore only case study evidence is available for this relationship.

How strong is the evidence?

3.5 The strongest evidence for this logic chain comes from hedonic economic studies which look for statistically significant relationships between proximity to greenspace and property prices. In general terms, there is strong evidence to support link a-b in the logic chain from these hedonic studies. Most of this evidence is international (Luttik, 2000, Crompton, 2005), but there are three policy studies in the UK which also support this link (GLA Economics, 2003, Neil Dunse *et al*., 2007, Garrod, 2002) It is also supported by qualitative interviews with property professionals (CABE Space, 2005) and evidence from a study assessing people's willingness to pay for forest views (Willis *et al*., 2003).

3.6 There are important caveats however. Firstly, proximity to greenspace is one of several issues people take into account when purchasing property, with travel to work and the social make-up of the area a stronger influence (GLA Economics, 2003). Secondly, parks can be the focus of anti-social behaviour, and this is often associated with parks being poorly maintained and unsafe places to play. Where this is either the case (Neil Dunse *et al*., 2007), or this is perceived to be the case (CABE Space, 2005), this will have a negative effect on property values, particularly on those immediately adjacent to the park, which may more than counteract any positive benefits. This may partly explain why the property price effect is much less clear in poorer areas where these problems are more common (Neil Dunse *et al*., 2007). Furthermore, the sort of rural views which increase property prices are quite specific, and marshland and dense forest may reduce property prices (Garrod and Willis, 1992). The actual impact will depend on numerous contextual factors including the size and quality of the greenspace, the local property market and economy.

3.7 It is common for reviews of link b-c to criticise the available evidence for being 'anecdotal'. It is important to be clear, however, that there is no way to prove this link on a quantitative statistical basis, because each case will be affected by too many contextual factors to control for. Key examples include general movement in the property market or economy, other regeneration improvements to the area which are often made at the same time, new transport links etc. Therefore, the evidence base is best advanced by case studies which carefully consider contextual factors, and in time meta-analyses, of these. There is case study evidence which suggests that improvement in greenspace acts powerfully to alter the perceptions of an area, which can therefore support property prices and regeneration (CABE Space, 2005). Additionally, there is also a district valuer's report which considers property price improvements and attempts to control for the relevant factors (Forestry Commission).

Examples and figures

Qualitative

- Interviews with property professionals show they expect higher prices for properties with park views, and near the park, in case studies of 8 significant English park redevelopment projects (CABE Space, 2005)[10].
- The development of a community woodland on the former Bold Colliery site in St Helen's is estimated to have directly and uniquely enhanced existing property values in the surrounding area by £15 million[11] (Forestry Commission).

Quantitative

- A study of house prices in Aberdeen showed that 'relative to a property located 450 metres away from a park, a property located on the edge of a park could potentially attract a premium of between 0.44% and 19%'[12] (Neil Dunse *et al*., 2007).
- A study of house prices in London found that 'on average a 1 per cent increase in the amount of greenspace in a ward can be associated with a 0.3 to 0.5 per cent increase in average house price[13] (GLA Economics, 2003).
- A view of forest can raise house prices by 7% and water by 5% (Garrod and Willis, 1992)[14].

- People are willing to pay £268.79p for houses with a woodland view and woodland views from properties therefore have an estimated value of £1.4 billion in England[15] (Garrod, 2002).

---

[8] See the evidence under the 'health and society' section for why this is the case.
[9] If you are not familiar with this distinction see **Chapter 1**.
[10] Case studies are Mesnes Park - Merseyside, Queen Square - Bristol, Boston Square Sensory Park - Hunstaton, Hulme Park - Manchester, Mowbray Park - Sunderland, Mile End Park - London, King George Rec Ground - Bushey, Lister Park - Bradford.
[11] This estimate is based on a district valuer's report which values indicator properties at various times and makes judgments as to the appropriate adjustment to allow for property alterations, the development of the M62 link road, new development and accessibility to adjacent localities. It is the view of a property professional, rather than a repeatable experiment (which are not possible for case studies like this). The strongest evidence that something special is going on is that house prices in St Helen's over the period under review grew slower than the national average, but in the vicinity of bold colliery they grew faster.
[12] This is the best house price based analysis in the UK because it includes smaller parks and uses Geographic Information systems to consider distance from the park. The large range of premiums for park edge properties is thought by the authors to be due to concern by house-purchasers about negative impacts of anti-social behaviour.
[13] This result was produced by a statistical analysis of London's wards which compared house prices with a number of relevant variables (known as a hedonic pricing method). It concluded that the percentage of strategic greenspace (space bigger than urban parks, private gardens and common spaces) was the 5th most important variable after the number of people on income support, travel time to central London, NO_2 average concentrations, and density of properties.
[14] This study is based on rural areas only and uses grid references so its conclusions are not based on specific views. Note that very forested environment might reduce house prices.
[15] This estimate is based on a choice experiment in which members of the public were asked to express their willingness-to-pay for certain views using photographs of different forests. This study uses a small sample and the headline figures are based entirely on results from a wealthy area of South East England. The study also does not take into account distance from view. The figure for England is an estimate based on wards classified as mixed urban and then multiplied by the percentage of those with woodland views in a survey (23%). Some caution is therefore required when interpreting these figures. However, the figures reported are only for broadleaved forest in a peri-urban setting because this was the only context in which a clear preference could be identified with such a small sample. It seems possible that a larger sample might find evidence of preferences for forest views in other contexts, in which case the figure quoted would be an under rather than an overestimate.

House prices - settlement or regional effects

Introduction

3.8 As well as the effects of the immediate vicinity, there is also discussion about the possibility of environmental quality affecting house prices in a whole area or conurbation, and this possibility is considered here.

Logic chain

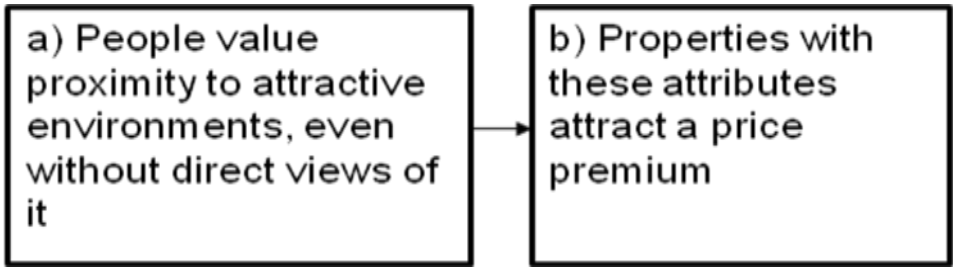

Figure 3

Can the benefit be quantified?

3.9 This logic chain is significantly more difficult to prove and to quantify than the one for houses with more direct access to attractive natural environments. Direct interviews with house purchasers might be the only way to build the evidence and this would be based on a stated preference, rather than revealed preference[16].

How strong is the evidence?

3.10 It has not been possible to locate any peer-reviewed research which addresses this question. However strong circumstantial evidence is available from the Lake District. See footnote for limitations.

Examples and figures

- House prices, within the Bassenthwaite catchment are 7 - 12 times local median income as against a Cumbrian average of 6.8:1. The median property price of £313,000 within the Derwent Valley ward is £146,000 above the Cumbrian average[17] (Rebanks consulting limited, 2010).

---

[16] Revealed preference is the stronger sort of evidence because people may miss-state their preferences when asked for social or strategic reasons, or because they are not clear themselves.

[17] This is evidence of a strong correlation between house prices and landscape quality in this part of the Lake District. Strictly speaking econometric research to control for other relevant factors should be conducted to assess how likely it is that the landscape is the driving factor, and how strong a factor it is compared to other things such as motorway access. It is certainly likely that social factors play a role, and it should be noted that Barrow-in-Furness is very close to the Lake District and has low house prices. Furthermore, as Rebanks points out, these house prices are driven by people who have made their money elsewhere moving into the Lakes, not by the dynamism of the Lakes' economy.

Inward investment - proximity effects

Introduction

There is a view that employers prefer to use commercial property with attractive green views from the office and direct access to greenspace. If this is the case it can be expected that this sort of commercial property will be worth more and attract greater rental. In order to understand the evidence in this section properly, and why increasing commercial property prices are **NOT IN THEMSELVES AN ECONOMIC BENEFIT**, please read the introduction to the domestic property prices section above. These arguments apply equally to commercial property prices.

Logic chain

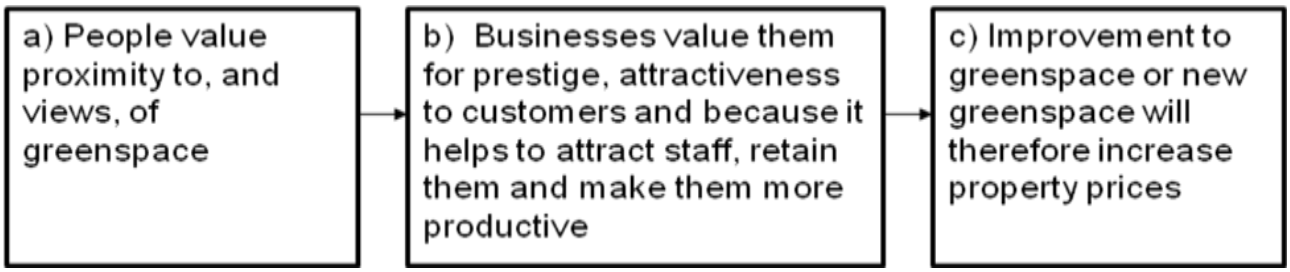

Figure 4

Can the benefit be quantified?

3.11 The relationships between proposed cause (views of and access to greenspace) and effect (increased property and rental values) could in principle be quantified although there are great challenges due to the number of contextual factors that would need controlling for. In practice the evidence is in the form of qualitative case studies.

How strong is the evidence?

3.12 The evidence in the **health and society** sub-chapter makes it reasonable to suppose that employees may prefer commercial environments with views of and/or proximity to nature, and that it might make them more productive. However, section b of our logic chain requires more than this, it requires businesses to be aware of these beneficial effects on their business and therefore to be willing to pay a premium for sites with view of and/or access to greenspace. The evidence that they are willing to do so is weak. CSI (2008) found that neither occupiers, nor developers nor property valuers expected improved landscape to affect property and rental values. However this research was undertaken in areas with low land value, and suggests that landscaping expectations are higher in higher value areas. For example, a survey of real estate developers and consultants across Europe found that 95% of respondents believe that open space adds value to commercial property (Gensler *et al*., 2011)[18]. This fits with many of the case studies which cover high land value business parks.

3.13 Much of the evidence which is offered seems to actually refer to an alternative logic chain in which it is the social relationships (status, crime rate etc) signaled by the landscaping that matter rather than environmental quality *per se*.

Examples and figures

- A survey of real estate developers and consultants across Europe found that 95% of respondents believe that open space adds value to commercial property and would be willing to pay at least 3% more to be in close proximity to open space. Respondents rated access to open space the 5th most important criterion when selecting commercial property, after

location, cost, public transport links, amenities but before prestige of address and building aesthetics (Gensler *et al*., 2011)[19].

- Green Park is a business park near Reading which has transformed 220 acres of low lying, partly contaminated agricultural land, into a 'green' office park surrounding a lake and boasting landscape and biodiversity awards as well as a new train station and wind turbine. The park is an economic success offering an annualized investment return of 19.8% (PRUPIM Developments)[20].
- Canary Wharf chose to build Jubilee Park in the middle of its office development at a cost of £6 million. Businesses used the park to sell relocation to the wharf to their staff, and Canary Wharf Group are confident they will recoup their investment (CABE Space, 2005).
- Arlington Business Parks has built an £800 million property portfolio offering offices in high quality greenspaces. These out of town parks command at least city centre retail values. Businesses using the office space consider the greenspace an important benefit[21] (CABE Space, 2005).
- A broadly mixed regeneration investment which included an element of landscaping, tree planting and rubbish clearance at Winsfield Industrial Estate in Cheshire was followed by a 13% increase in employment against a small decrease in employment in the local area (CLES Policy Advice, 2007)[22].
- A broadly mixed regeneration investment which included an element of landscape, tree planting and rubbish clearance in Portland Basin, Tameside, was followed by a 25% increase in employment against a background increase of 8.3% in the local area (CLES Policy Advice, 2007)[23].
- Investment in Glasgow Green coincided with a rate of local new business formation that was much faster than that for Glasgow has a whole. Business located next to the regeneration of Glasgow Green felt that the location was attractive to customers and increased improved staff morale and retention[24] (GEN Consulting, 2006).

---

[18] The survey respondents were 48% advisers, 21% developers, 19% investors and 12% public sectors investors. Although the survey used the definition of open space respondents rated greenery, restful spaces and security as the most important concerns.
[19] A figure of 93% of respondents willing to pay an extra 3% is given for London. Case studies of New York Hamburg and London are also offered in this document.
[20] Note that this is at the expensive end of the commercial market for office space.
[21] Note that this is at the expensive end of the commercial market for office space.
[22] It seems likely that this study is evidence of an alternative logic chain, which is more about social signals and perceptions than about the benefit of greenspace *per se*.
[23] It seems likely that this study is evidence of an alternative logic chain, which is more about social signals and perceptions than about the benefit of greenspace *per se*.
[24] The edge of the city centre location was also central, but the regeneration may have contributed to making the area feel like a viable investment proposition.

Inward investment - settlement or regional effects

Introduction

3.14 As well as the effects of proximate greenspace on property prices, there is a more general argument that the attractiveness of cities, towns and whole sub-regions to inward investment is enhanced by environmental quality. Evidence for this could be picked up in commercial property prices, but also in flows of inward investment and on the basis of interviews with businesses and experts in business relocation. In order to understand this section please read the introduction to **House prices - proximity effects** which explains why **INCREASED PROPERTY PRICES IS NOT AN ECONOMIC BENEFIT**. This argument applies to this section with the important exception that it is about attracting investment from outside a local authority area, and possibly from outside the country. This means that although this section is also about **relative attractiveness** rather than absolute productivity, from the point of view of a local authority the new investment is a boost to their economy.

Logic chain

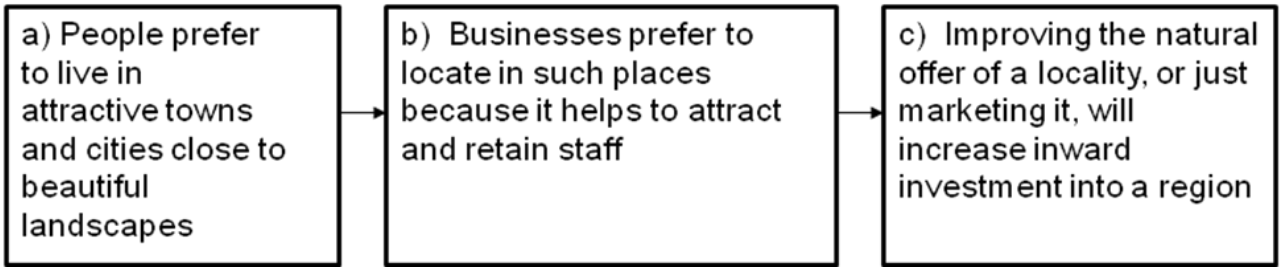

Figure 5

Can the benefit be quantified?

3.15 In this case the challenge of stripping out contextual factors is too great, and therefore only case study evidence is available. These case studies will include numbers, but there is no reliable method of establishing a quantitative causal link.

How strong is the evidence?

3.16 Like the section above for more proximate effects, this logic chain depends on more than the beneficial effects of the environment, but also depends on businesses believing that these effects will influence their bottom line. A naïve version of this logic chain is easy to knock down. Research into business relocation shows that workforce skills, business diversity and innovation and connectivity are top of businesses priorities when choosing a location (Parkinson *et al*., 2004). This explains the dominance of London with regard to inward investment. However, once the main criteria are satisfied businesses do suggest that quality of life factors, which include environmental quality do have an impact on location decisions (Parkinson *et al*., 2004). The more subtle argument is that a certain type of high-value added, knowledge economy business, needs to attract a particular sort of staff who are more concerned about these issues. However, I have been unable to find evidence of a robust survey of businesses to support this logic chain, and this is the strongest form of evidence likely.

Tourism and recreation

Introduction

3.17 Tourism is the UK's fifth largest industry with an economic **IMPACT** of £115 billion (Deloitte and Oxford Economics, 2010) . This makes attracting tourism and recreation an important element of local authority economic development plans. Improvements of economic tourism and recreation performance by a local authority are relative, rather than absolute economic benefits, in that they will be at the expense of a competing destination or economic sector. However, to the extent that the English tourism is in competition with international destinations, it is a benefit to 'UK PLC'.

Logic chain

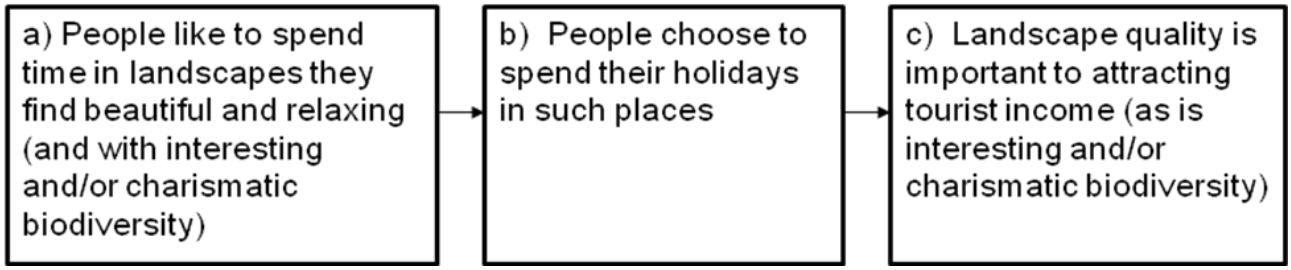

Figure 6

Can the benefit be quantified?

3.18 It is possible to quantify relationships for this benefit, and most or the research seeks to do exactly this. It is worth noting, however, that for the vast majority of studies the quantified link is based on responses to questionnaires by the public - hence the quantitative connections are based on declared rather than revealed behaviour[25]. Additionally assessments of economic impact necessarily rely on assumptions about multipliers and linkages, making them estimates.

How strong is the evidence?

3.19 In one sense, this logic chain is obviously true. Most of the economic **IMPACT** of tourism is in cities and large towns, but a significant proportion is rural and seaside (Deloitte and Oxford Economics, 2010). Rural tourism may be particularly welcome as it is a growing economic sector in localities were many traditional agricultural and industrial industries are declining (Shiel *et al*., 2002). However, it would be wrong to assume that all rural tourism is particularly concerned with landscape or biodiversity quality - for example 4x4 experience days have minimal dependence on these (Roberts and Hall, 2004). In practice there is a spectrum from this through to landscape painting and bird watching which depend entirely on landscape quality and biodiversity. It is also important to note that, in an English context, the landscape and biodiversity which attracts tourism is unlikely to be wild and is likely to require management to maintain its attractive features. Neither is it necessarily the case that attractive landscapes are necessary healthy in biodiversity terms. Nature-based holidays may be based around activities such as walking, which although they may have great **VALUE** to those taking part, lead to limited economic **IMPACT** because they require little expenditure. Lastly, it is not necessarily the case that those taking part in rural tourism have particularly 'environmental values' or that rural tourism is more environmentally friendly than urban tourism. There is therefore not necessarily any virtuous circle between environmental tourism and environmental quality (Roberts and Hall, 2004).

Examples and figures

Nationwide England or UK

- It is estimated that visits by UK residents to the countryside and/or villages contribute £5.5 billion annually for the economy in England and that visits by UK residents to the seaside contribute £7.4 billion annually[26] (Deloitte and Oxford Economics, 2010).
- It is estimated that visitors to the English Countryside in 1998 spent £11.5 billion and this generated some 340,000 jobs[27] (The Countryside Agency, 1998).
- It is estimated that walking in the English Countryside leads to £6,139 million of expenditure, with an economic impact between £1,473 and £2,763 million, and supporting between 180,559 and 245,560 F.T.E. jobs[28] (Christie and Mathews, 2003).
- It is estimated that tourist day visitors spent between £54,000 and £72,000 per year on the average forest site in England, with £7.43 average forest related expenditure per visit[29] (Hill *et al*., 2003).
- It is estimated that forest-related tourism expenditures on day visit to forests are about £2.1 billion per year. This represents about 3.4% of total tourism spending[30] (Hill *et al*., 2003).
- It is estimated that RSPB reserves support more than 1,000 F.T.E. jobs in the UK, and because they tend to be on less favourable agricultural land, tend to lead to an increase in economic activity when acquired[31] (Shiel *et al*., 2002).
- It is estimated that recreational visits to Forestry Commission estates have an economic value of £3.354 million per annum[32] (Willis and Garrod, 1991).
- It is estimated that people visiting Osprey watching sites in the UK bring total additional expenditure of £3.5 million per year to the areas around the sites[33] (Dickie *et al*., 2006).

England sub-national

- It is estimated that landscape motivated holiday trips to the South West support 71,400 f.t.e. jobs (National Trust, 1999)[34].
- It is estimated that tourists spend £191 million in North and West Norfolk and that this provides 7,870 jobs f.t.e. representing 17.5% of employment in the two districts. A survey of six sites on the coast associated with landscape and biodiversity estimated that the annual spend of visitors to these sites was £21 million which supports 442 jobs f.t.e.[35] (Rayment *et al*., 2000).
- It has been estimated that Minsmere RSPB reserve in Suffolk support 50 jobs in the local economy[36] (Rayment and Dickie, 2001).
- It is estimated that Leighton Moss RSPB reserve, and neighbouring sites in Silverdale, Lancashire attract visitor spending of at least £0.95 million per year to the local economy within 20 miles of the reserve. It is estimated that the reserve supports 59 f.t.e. jobs directly or indirectly[37] (Rayment and Dickie, 2001).
- It is estimated that £420,000 of the £1.68 million spent by visitors to the Dodd Wood and Whinlatter part of the lakes was due to the presence of Ospreys[38] (Dickie *et al*., 2006).
- It is estimated that £154,000 of the £678,00 spent by visitors to the Rutland water reserve in 2005 was attributable to the presence of the Ospreys[39] (Dickie *et al*., 2006).
- It is estimated that the presence of choughs in the Lizard area of Cornwall attracted an additional £118,000 supporting the equivalent of 3.2 full time jobs[40] (Dickie *et al*., 2006).
- It is estimated that Symond's Yat Rock in Gloucestershire attracts £0.5 million of visitor spending to the Forest of Dean each year[41] (Dickie *et al*., 2006).
- Wren's Nest is a National Nature Reserve (NNR), designated for its geo-diversity interest in the Dudley area of the West Midlands. It has been estimated that access to the NNR with interpretive material is worth £21.26 per household per year. Additionally, the ability to collect fossils from the site (with the proviso that important fossils were protected) was valued at £6.58 per household per year[42] (Webber and Christie, 2006).

- It is estimated that access to the Jurassic Coast with interpretive material was worth £62.35 per household per year. Additionally public fossil collecting (with a code of conduct to protect important fossils) was valued at £57.73 per year[43] (Webber and Christie, 2006).

Outside England

- It is estimated that £1.4 - £1.6 of the £38 million spent annually by visitors on the Isle of Mull is attracted by the presence of sea eagles. It is estimated that this is worth 36 - 42 full-time-equivalent jobs on Mull[44] (Dickie *et al*., 2006).

---

[25] Revealed preference is the stronger sort of evidence because people may miss-state their preferences when asked for social or strategic reasons, or because they are not clear themselves.
[26] These estimates are based on a bespoke model developed by Deloitte and Oxford Economics which is driven by nationally available data sets (UK Travel Survey and International Travel Survey mainly). The methodology as explained in the document seems appropriate, but has not been reviewed for this package. Page 20 includes some useful estimates of the most tourism dependent areas of the UK.
[27] This estimate has been generated from the UK Day Visits Survey, the UK Tourism Survey and the international passenger survey. It includes an assumption that international tourists have travel and expenditure patterns which are the same as those for domestic tourists, but this will not alter the estimate significantly. 'Countryside' is self-defined by survey respondents. The jobs supported estimate is based on earlier research in 1994 which involved a triangulation of a sectoral impact approach and the Cambridge Economic Impact model. The report reviewed does not provide enough data to assess these approaches fully, but the working seems careful and appropriate.
[28] This estimate has been generated from the UK Day Visits Survey, the UK Tourism Survey and the international passenger survey. The numbers include all those who said that a walk was part of their day out, and so it is not limited to travelers for whom walking is the main purpose of their visit. Additionally, it is based on assumptions, such as that walking tourists have an average expenditure pattern similar to non-walking tourists and international tourists behave like domestic tourists: but this will not alter the estimate significantly. The approach used to economic impact and employment effects is based on the RSPB work and appears appropriate. This is therefore a reasonable but upper end estimate.
[29] This estimate is based on the coupling of interviews at forestry sites and an attempt to fit a statistical model estimating visits based on variables such as population living near each site, substitute sites and population characteristics. Although the approach is appropriate authors admit that the **OUTCOME IS NOT STATISTICALLY ROBUST, BUT SHOULD BE CONSIDERED A BEST GUESS GIVEN THE STATE OF THE DATA**. Note also that this is an estimate of economic significance, which means that no claim is made that this expenditure is additional and would not have been spent somewhere else if it had not been spent on a forest site. The estimate includes people on holiday and those taking a trip of more than three hours.
[30] This estimate is based on the coupling of interviews at forestry sites, other tourist locations and use of the UK Day Visitor Survey from the Countryside Agency in 1998, and is therefore only as robust as this survey. With this exception assumptions used are spelled out and conservative. Note also that this is an estimate of economic significance, which means that no claim is made that this expenditure is additional and would not have been spent somewhere else were the forest location not available. The estimate includes people on holiday and those taking a trip of more than three hours.
[31] This figure is based on direct employment, expenditure (including on contractors), grazing lets and agricultural tenancies and the impact of spending by employees, volunteers and visitors to the reserve. The methodology is conservative and appropriate.
[32] This estimate is on an analysis of surveys looking at the travel cost of visiting particular forest sites, with six different types of forest site considered, with substitute forests considered. The method used is appropriate, but extremely conservative and the result must be considered a lower bound estimate.
[33] This estimate is based on a mixture of results from RSPB studies, studies by a third party - McCraight - and reasonable extrapolation to non-surveyed sites. The assumptions are reasonable and conservative and the methodology appropriate.
[34] This estimate is based on interviews with people leaving the South West at service stations. They were asked to give their motivations for visiting proportionately out of 10. The average score for the conserved landscape was 7.8 so the tourism expenditures from the UK Tourism Survey and international passenger survey were multiplied by 0.78. The Cambridge Economic Impact of Tourism model by Geoff Broom Associates (which I have not yet reviewed) was used to convert this into direct (47,500) and indirect employment (23,900). The same methodology produced figures for counties; Cornwall 28,500; Devon 32,500; Dorset 13,400; Gloucestershire 3,500; Somerset, and the counties that used to be Avon 14,600; Wiltshire 2,900.

[35] The methodology in this RSPB research is conservative and appropriate. The first set of figures which relate to West and North Norfolk are estimated from nationally available databases by Geoff Broom based on the Cambridge Economic Impact of Tourism Model (which has not been reviewed). The second set of figures which relate to the six sites is based on interviews at the six sites and then feeding these figures into the Cambridge Economic Impact of Tourism Model (which has not been reviewed). It seems highly likely that a significant percentage of tourism to the area is attracted by biodiversity and landscape quality, but because this research, which was carried out by the RSPB focused on sites of specific interest to wildlife enthusiasts it is not possible to generalize to the wider population. Estimates of jobs attributable to individual sites are Blakeney Quay 96 f.t.e.; Cley NWT Reserve 55 f.t.e.; Holkham Lady Anne's Drive 23 f.t.e.; Morston Quay 58 f.t.e.; Snettisham 11 f.t.e.; Titchwell 41 f.t.e..

[36] This research is based on an MSC dissertation by Astman. The methodology as reported is conservative and appropriate, and RSPB economists have chosen to publish it. The results are generated from a survey of visitors to the site and the assumption that one f.t.e. job is supported by £40,000 of expenditure (this is higher than the national average to account for Suffolk's above average per capita incomes). The figures includes direct and indirect employment due to both visitor and RSPB expenditure.

[37] This review is based on a summary of a longer report by Cooper and Rayment. The expenditure figures are calculated based on surveys from people attending the reserve and apportioning their expenditure depending on whether the reserve was the main reason for visiting the area. The employment figures are based on estimated expenditure by visitors from outside the area, and expenditure by the RSPB and linkage and multiplier effects from both. They assume a local employment multiplier of £35,000 per f.t.e. job (Rayment and Dickie, 2001).

[38] This estimate is generated from an RSPB study in which visitors filled in questionnaires detailing what they had spent and whether seeing the Ospreys was the main reason for the trip, a reason, or irrelevant. The methodology is appropriate and conservative.

[39] This estimate is reported by the RSPB but based on a study by McCraight in which visitors filled in questionnaires detailing what they had spent and whether seeing the Ospreys was the main reason for the trip, a reason, or irrelevant. The methodology (to the extent it is described) appears appropriate and relevant.

[40] This estimate is based on research by the RSPB but based on a study in which visitors filled in questionnaires detailing what they had spent and whether seeing the Choughs was the main reason for the trip, a reason, or irrelevant. The methodology appears appropriate and relevant.

[41] This result is based on the updating of results, from a reported study by Andrew Case in 1999, to 2005 visitor numbers and pounds.

[42] This result is based on a choice experiment, in which a sample were asked to choose between different scenarios in which attributes and tax rate vary, thus allowing the calculation of an implicit price for the attributes. The survey methodology was appropriate. Should you wish to quote the respective household values multiplied for the whole of the appropriate local authority they are £1,421,612 for access with explanation of geology and £987,519 for collecting fossils (with protection for important fossils). I have chosen not to use these figures because they require additional assumptions. Certainly do not multiply the per household figures by the UK or global populations!

[43] This result is based on a choice experiment, in which a sample were asked to choose between different scenarios in which attributes and tax rate vary, thus allowing the calculation of an implicit price for the attributes. The survey methodology was appropriate. I have chosen not to include the aggregated figures in the study for the per household value multiplied by the number of residents of the two adjacent local authorities, because many of those included in the sample were visitors who may be from outside this area. Therefore it is not obvious what the appropriate population to multiply by is.

[44] This estimate is generated from an RSPB study in which visitors to the Isle of Mull filled in questionnaires detailing what they had spent and whether seeing the Sea Eagles was the main reason for the trip, a reason, or irrelevant. The methodology is appropriate and conservative and fits well with a previous study and observed tourism spend.

Labour productivity

Introduction

3.20 It is often suggested that investment in Green Infrastructure boosts productivity at work. On the basis of the affects of relationship with natural environment on the lives of employees there is evidence for this proposed effect, and this is reviewed under the **health and society** sub-chapter. This section reviews the evidence for the narrower proposal that that quality of the natural environment at the place of work makes a difference to productivity. This includes the effect of nature in the indoor environment, views of nature from the windows, and accessible greenspaces in the grounds of the office or factory. There is a close relationship with the **Inward Investment - proximity effect** section, but this section is about the benefit derived, rather than business behaviour as a result of the benefit derived.

Logic chain

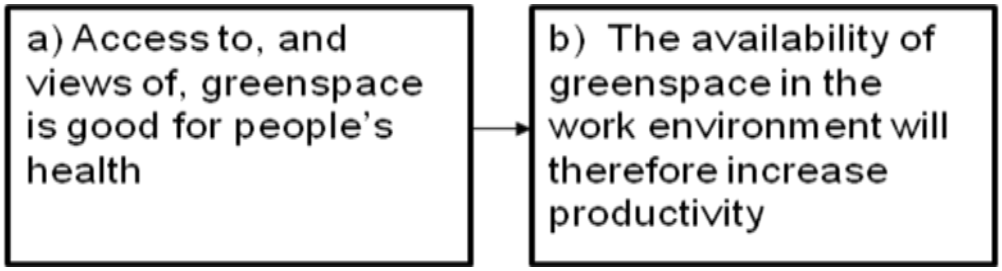

Figure 7

Can the benefit be quantified?

3.21 The number of confounding contextual factors is too great for convincing quantification of the relationship, therefore although quantitative quasi-experiments are possible, a rule based quantitative linkage between variables is not.

How strong is the evidence?

3.22 The general basis for the importance of the environment near work is made in the **health and society** section. Indeed the Health Council of the Netherlands (2004) review of the evidence concludes that an attractive green environment, close to home and work provide the best opportunities to encourage exercise in the form of walking and cycling[45]. The majority of these benefits will be due to features outside the property boundary, making selection of office site important, but there is also potential to offer relaxing greenspace within the grounds.

3.23 On the more specific issues as to whether office plants increase productivity, the evidence is less clear. There has been a great deal of research on the benefits of indoor plants. Some research in hospitals have found that people have higher levels of pain tolerance with plants present, and there has also been some research which finds benefits in terms of productivity in offices, although results are mixed (Bringslimark *et al*., 2009). However, partly due to some weaknesses in the experiments reported, and partly due to the complex contextual nature of the issue both Bringslimark (2009) and the Health Council of the Netherlands (2004) regard the evidence as strongly suggestive, but not proven with regard to a generalised causal link.

[45] Please note the qualifications in the health and society section.

4 Evidence organised by ecosystem service

4.1 This section will provide evidence about the benefits of green infrastructure interventions organised in terms of ecosystem services. This approach has the benefit of a relatively clear and distinct organizational framework, which helps to make clear what the service is and how the natural environment is providing it. A note of caution is necessary in terms of communicating these benefits to decision makers however; they may be put off by very conceptual terms such as ecosystem services, particularly if it is used to often. It is therefore better to focus on the services, such as flood control, or health benefits which are directly understood as relevant to policy maker's agendas. Additionally, because policy makers tend to think in themes, rather than services, evidence is presented differently in Chapter 3 and pulled together thematically in Chapter 2.

4.2 Ecosystem services are often grouped, and this is the approach taken here:

- **Health and society services** - these are to do with the non-material benefits we derive from our relationships with nature, for example the relaxing effect of a walk in the park;
- **Regulatory services** - these are the ways in which nature regulates the environment in ways beneficial to humans, such as flood control and climate regulation;
- **Provisioning services** - these are the products we receive from nature and consume directly such as food and fresh water; and
- Supporting services - these are natural functions which are necessary to support all the other services. Examples include the soil formation and health, photosynthesis and pollination. These are not given their own section in this report because it would lead to repetition; instead they feature where relevant in the section above.

4.3 It is important to note that here not all ecosystem services are included here. The ones chosen are the ones which on the basis of current evidence are most important in the context of Green Infrastructure projects. The ones selected are also amongst those for which we have the best evidence available natural science and economic evidence. There is the potential for future editions of this review which will expand the range included.

4a: Health and society

4.4 This section reviews the cultural and health benefits offered by green infrastructure. The first section is about health in general.

Health general

Introduction

4.5 This section reviews generic evidence related to the benefits of having greenspace close to where you live. From the point of developing research it is very important to separate out psychological health, physical health and social effects. However, from the point of view of some specific interventions, working out which element is delivering the benefit is less important, because all three are bundled together and maybe mutually reinforcing. For example, the Walking for Health programme combines time spent in greenspaces, with exercise and new social contacts.

Proposition

4.6 Areas with more greenspace are better for population health than areas with less greenspace.

How strong is the evidence?

4.7 There are a number of studies which show a statistically significant correlation between the quantity of greenspace within proximity of a population and positive health outcomes. Crucially, these studies control for socio-economic and demographic variables and therefore rule out the alternative causal explanation that healthier people are choosing to live in areas with more greenspace. Two of these studies are from the Netherlands

4.8 [46] (De Vries *et al*., 2003, Maas *et al*., 2006), one is from Japan (Takano *et al*., 2002), and one is from the UK[47] (Mitchell and Popham, 2008). These studies provide evidence of a generalised effect, but do not offer evidence of the cause of that effect[48]. Neither can these general results be easily applied to a local level where a myriad of complicating contextual factors must be taken into account such as area deprivation and perceived access (Jones *et al*., 2010).

Discussion of contextual factors

- Evidence suggest that people access greenspace much more when it's within short walking distance[49] (Giles-Corti *et al*., 2005, Neuvonen *et al*., 2007).
- Poor quality greenspace, with problems with dog mess, vandalised equipment and graffiti is associated with concerns about personal safety and has a negative impact on neighbourhood's self perception (Urban Green Spaces Task Force, 2002).
- People in deprived areas are most likely to be losing out on the benefits of high-quality greenspace[50] (Urban Green Spaces Task Force, 2002).
- Some groups use parks less than the rest of the population, these include people over 65, people with disabilities, people from black and ethnic minority communities, women and 12 to 19 year-olds[51] (Urban Green Spaces Task Force, 2002).
- An important factor limiting the benefit people get from greenspace is fear of attack. Research in Leicester shows that this disproportionately affects women, the elderly, Asian and African-Caribbean people (Madge, 1997).
- Research in Scotland suggested that social and cultural interventions may improve use of local forests, particularly engaging local communities, and providing mediation between different users (Weldon *et al*., 2007).

[46] The Dutch studies both found that the effect was strongest on those most likely to be dependent on their local environment, ie those at home caring for children, elderly, lower educated. This is both an important finding, and fits with the hypothesis, strengthening the credibility of the results.
[47] This study focussed on the social gradient of health inequalities. The findings supported the hypothesis that access to greenspace reduced the gradient of health inequalities, suggesting it provided a mechanism to ameliorate the ill-health pathway. The fact that the significant relationships with all-cause and circulatory disease were found, but significant relationships with lung cancer and intentional self-harm weren't, fits with the hypothesis, strengthening the credibility of the results.
[48] Although the Japanese study specifically used 'walk-able' greenspace in its analysis.
[49] These peer-referenced studies are from Australia and Helsinki respectively. Climatic context is sufficiently varied to think this should apply to the UK!
[50] The figures used to back up this assertion are now a decade out of date, but this is currently the best reference found for this widely accepted point.
[51] These comments are taken from an official government report, rather than peer-referenced research. This reference is preferred to international peer-referenced research into other countries as local contextual factors are important here.

Psychological benefits of exposure to natural environments

Introduction

4.9 This section presents evidence that exposure to natural environments has psychological benefits, particularly with regard to stress levels and mood. This will include the psychological benefits of exercise taken in a natural environment as opposed to in an unnatural one.

4.10 Evidence of a positive impact on mental health is important because mental health is a significant problem in England with strong negative impact on the economy - see figures below (Layard, 2006). Tackling chronic stress is important because it plays a major role in the causation and development of common physical and mental illnesses, and the problem has been intensifying in recent decades[52] (Health Council of the Netherlands, 2004).

Proposition

4.11 Exposure to natural environments has psychological benefits which are significant enough to have an effect on mental health.

Can the benefit be quantified?

4.12 Quantification of these relationships is extremely difficult. The only robust empirical route is through a longitudinal study, which would have to be quasi-experimental, because randomly assigning people to groups over the long term would contravene ethical requirements. The evidence must therefore be reviewed with a sense for the sort of evidence which is possible. In practice, this link may not be prove-able in strict experimental terms, which means that the case must be developed through close attention to qualitative and high quality quasi-experimental studies.

How strong is the evidence?

4.13 There is strong evidence, from a large number of high-quality studies that nature promotes recovery from stress and attention fatigue, and that it has positive effects on mood, concentration, self-discipline, and physiological stress (Health Council of the Netherlands, 2004) [for examples see (Kaplan and Kaplan, 1989), (Berman *et al*., 2008),(Ulrich, 1984) and (Ulrich *et al*., 1991)]. There is also research which shows reduced Attention Deficit Disorder symptoms in children after playing in a green environment (Taylor *et al*., 2001). However, in terms of a beneficial effect on chronic stress it is the impact over the long-term which matters most, and there is as yet insufficient scientifically rigorous research into this (Health Council of the Netherlands, 2004). On the specific issue of whether exercise in greenspace had mental health benefits greater than indoor exercise, a systematic review of the evidence for the mental health benefits of taking exercise in greenspace found significant reductions in anger, fatigue and depression, but concluded that there was not yet enough evidence to make generalized statements of universal benefit (Bowler *et al*., 2010b).

4.14 A study by Grahn and Stigsdotter (2003) in Sweden represents the most powerful quasi-experimental evidence for longer term effects[53]. A study of Swedish town dwellers found statistically significant relationships between the use of urban greenspace and self-reported levels of stress. The results showed that the more often a person visited greenspace the less they reported stress-related illnesses, and that distance to greenspace was crucial to the amount they were used. A similar study in Denmark (Nielsen and Hansen, 2007) also finds links between distance to greenspace to be statistically linked to mental health outcomes. Guite *et al*. (2006) performed a study in Greenwich, London, looking at the local environment in its broadest sense (ie, fear of crime, noise etc) and also include that being dissatisfied with access to open greenspace is related to mental ill-health in a statistically significant manner[54]. On the specific issue of children's cognitive functioning, a longitudinal study suggests objectively greener environments are linked to objectively measured improvements (Wells, 2000).

4.15 Of particular interest to Natural England is the question as to how natural the greenspace has to be. The evidence in this area is not as developed as for the benefits of greenspace in general, but there is a study which found increased psychological benefit for greenspaces with higher levels of biodiversity[55] (Fuller *et al*., 2007). Additionally a study in Montpellier, France found that 72% of respondents preferred natural to ornamental greenspaces[56] (Caula *et al*., 2009).

Examples and figures

- A rigorous sample-based survey suggests 1 in 6 people in the UK have depression or chronic anxiety disorder with just under 1 in 4 people suffering from some form of mental illness[57] (McManus and Bebbington, 2009).
- 40% of those on Incapacity Benefit are there due to mental illness - a million people[58] (Layard, 2006).
- The economic and social costs of mental illness in England are estimated at £77.4 billion for the year 02/03. This includes direct costs of healthcare of £8.4 billion, non-employment costs of £9.4 billion and sickness absence of £3.9 billion[59] (The Sainsbury Centre for Mental Health, 2003).
- Preferences for views of nature are another sort of evidence. It is estimated that people are willing to pay £226.56p per year for woodland views whilst travelling with an estimated value for England of £2.1 billion[60] (Garrod, 2002).

---

[52] The comments in the report refer primarily to Dutch society, but it does not seem too great a stretch to apply them to the UK. On the basis of these comments the report argues that chronic stress should have a profile in public health policy similar to that of alcohol and smoking.

[53] The study selected the Swedish residents randomly and controlled for age, sex and socio-economic status. Given practical and ethical constraints this may be as close to a genuine experiment as is possible for long-term study.

[54] In this study the survey was not sent randomly, but based on a previously held theoretical model of domains which might influence mental health. A wide range of possible confounding variables was considered. Given practical and ethical constraints this may be as close to a genuine experiment as is possible for long-term study.

[55] This study assessed biodiversity and self-reported psychological responses on a robust basis in parks in Sheffield. It found that park-users perceptions of plant biodiversity were strongly related to objective measures, for birds there was the appearance of a relationship, but it wasn't strong enough to be statistically significant, and for butterflies there was no clear relationship. The degree of psychological benefit was positively related to the species richness of plants. Obviously, it was not possible to control whether people with a greater propensity to psychological benefit from greenspace choose to visit more biodiverse parks, so this is a potential confounder. The findings suggest that park management emphasizing a mosaic of habitats would benefit biodiversity and the psychological wellbeing of park visitors.

[56] This peer-reviewed study was based on a self-completed study distributed to community centres in Montpellier. Appropriate comparisons between those completing the survey and population were made and the sample proved to be broadly comparable to the population, but contains a smaller percentage of people with lower levels of education. The study also found that for those most interested in urban biodiversity, and for those that make the most use of greenspaces, providing information about the importance of greenspaces for biodiversity increased willingness to pay for natural greenspaces.

[57] The nearly 1 in 4 figure is actually 23% and includes people suffering from post-traumatic stress disorder, suicidal thoughts, suicide attempts and self-harm, psychosis, anti-social and borderline personality disorders, attention deficit and hyperactivity disorders, eating disorders, alcohol misuse and dependence, drug-use and dependence, gambling behavioral problems.

[58] Layard references DWP.

[59] Note that the £77.4 billion figures is an economic **VALUE** estimate and so cannot be compared to GDP figures. The approach taken includes valuing unpaid work and also quality of life year's lost and therefore must be regarded as a best estimate, and in future could be improved upon in terms of methodology and data availability. However the approach taken is appropriate and conservative. The other figures I have pulled out of the analysis are economic **IMPACT** figures, and can appropriately be compared to GDP.

[60] This refers to peri-urban broadleaved woodland and is based on a choice experiment, in which people were asked to choose preferred options from scenarios which included costs and views. The value for England was based on a statistical assumption of likelihood of rural dwellers encountering such a view during a commute. The

study however is based on a small sample in a wealthy part of South-East England, and in this sense could be an overestimate.

Increased likelihood of physical activity

Introduction

4.16 It is well established that increased physical activity has significant health benefits for those not meeting recommended activity levels and some of the main references are included here. However the focus of this section is to consider the evidence that people are more likely to undertake (or maintain) activity when they have access to greenspace. This may be due to the psychological benefits of spending time in nature covered in the last section, but may also be due to the comparative ease with which recreational visits to parks or active travel can be added to a daily routine, as opposed to attendance at a gym.

Logic chain

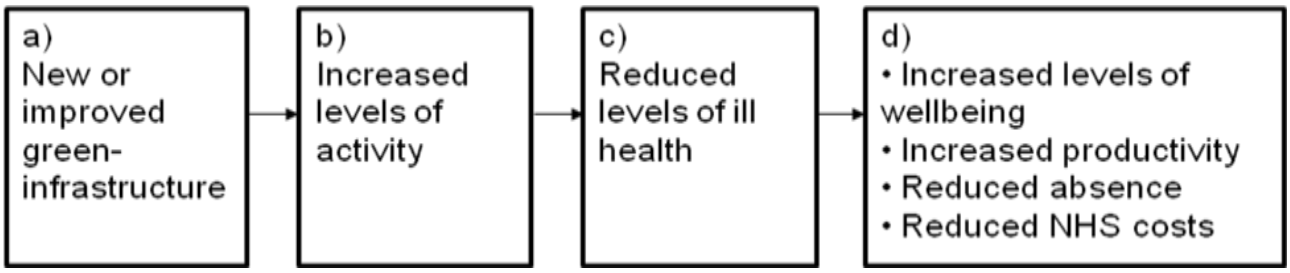

Figure 8

Can the benefit be quantified?

4.17 In principle, the health outcomes of increased levels of activity can be quantified (on an appropriate average basis) and this can then be linked to health outcomes and economic impacts which can be valued. Tools to do this for walking and cycling are under development by the World Health Organisation. The difficulty in quantifying the relationship between the new or improved green infrastructure and any change in activity levels, particularly given the need to allow for substitution effects (ie is it new exercise, or merely transferred).

How strong is the evidence?

4.18 The evidence base will be presented using the logic chain above, starting with the evidence connecting section b, c, and d, which is well established. There is very strong evidence for the benefits of increasing physical activity to the recommended levels, with the Chief Medical Officer (2004) reporting that it is as important as diet and smoking cessation. Additionally, exercise reduced the risk of obesity which is a risk factor in a range of chronic diseases, particularly type 2 diabetes, stroke and coronary heart disease and also cancer and arthritis (Foresight, 2007). Furthermore, people who lead an active lifestyle over several years have a reduced risk of clinical depression and physical activity is effective as a treatment of mild, moderate and severe depression (Chief Medical Officer, 2004). There is evidence that for serious mental illness exercise is as effective as medication (Richardson *et al*., 2005), but without the significant negative side effects (MIND, 2007).

4.19 We now move to the most difficult section of the logic chain, the link between greenspace, or greenness, and increased activity levels. This is difficult and complex and so the argument is built up piece by piece. Firstly, inactivity is a rapidly growing problem, so what is it that has changed? It is **not** a decline in organised sport and active leisure, which has seen a slight increase, but a major decline in everyday exercise, at work, in the home and through active travel (Chief Medical Officer, 2004). This suggests that this everyday exercise could be a focus for attempts to increase activity levels. This fits well with a review of programmes to encourage exercise for health reasons, which suggests that the most effective interventions to increase activity levels involve walking from home and do not involve attendance at a facility (Hillsdon and Thorogood, 1996).

4.20 Having established active travel and outdoor leisure as important elements in a campaign to reduce inactivity, we can then show that the qualities of the local environment are important in encouraging people to make these choices (Health Council of the Netherlands, 2004). What we mean by the environment here is broader than greenery but encompasses street/pavement quality, traffic volumes, safety, routes, attractiveness and the quality of local destinations: all are important determinants of exercise levels (Pikora *et al*., 2003). An official government review into the evidence around obesity concludes that exhortation to individual behaviour change will be insufficient to prevent the growing trend to obesity and that a whole system approach is needed, including 'redesigning the built environment to promote walking' (Foresight, 2007).

4.21 So, the environment in the broadest sense may be an important factor in encouraging walking and cycling for both leisure and transport, but we need to consider whether green infrastructure has a role to play in encouraging this. The evidence presented under **psychological benefits** and **economic competitiveness** suggests this strongly that this might be the case. The Health Council of the Netherlands (2004) review suggested that although there was a limited amount of research directly into this question, the research that there is suggestive of a connection. An example is Takano ***et al's*** (2002) longitudinal study in Tokyo which demonstrated that walkable greenspace positively influenced the longevity of urban senior citizens[61].

4.22 The argument so far gives good reason to think that new or improved greenspace has a role to play in the promotion of physical activity. The strongest claim which is made is that there should be a relationship between access to formal greenspace and levels of activity. However, the evidence for this is weak. Cohen's (2007) research in deprived predominantly ethnic minority areas of Los Angeles found that residents said that parks were the most important place to exercise and that only 13% of park users lived more than 1 mile from the park[62]. However, this research took place in Southern California, which for climatic reasons is likely to have an outdoor exercise culture. Nielsen and Hansen's (2007) study in Denmark found a statistically significant relationship between access to a garden or local greenspace and lower levels and stress and obesity[63]. However, they concluded that the strength of the effect was too strong to be explained only be visits to these spaces and that this may be an indicator of an area more conducive to spending time outdoors and active travel. It is therefore not necessarily surprising that results here are mixed. Hillsdon *et al* (2006) find no significant relationship between distance to, and quality of parks and activity levels[64] (Hillsdon *et al*., 2006). On the other hand Coombes *et al*[65] (2010) found a relationship between levels of activity and distance to a formal park, even when controlling for respondent and area characteristics. Furthermore they found that those living further from greenspaces were less likely to meet guidelines physical activity levels and more likely to be overweight or obese[66]. In conclusion, green infrastructure interventions have an important role to play as part of a holistic policy for promoting activity, but this should not be overstated.

4.23 Research into why people visit parks shows that biodiversity is an important motivating factor. For example 27% visit to enjoy flowers and trees, 22% visit to see birds and wildlife (Greenspace, 2007) making biodiversity a reason for (potentially active) travel (Bird, 2004).

Examples and figures

- At least 30 minutes a day of moderate intensity exercise five days a week is recommended for general health, but for many people 45 - 60 minutes a day will be needed to prevent obesity[67] (Chief Medical Officer, 2004).
- Two-thirds of men and three-quarters of women report activity levels which substantially increase their risk of contracting a broad range of chronic diseases (Chief Medical Officer, 2004).
- The UK has the highest adult obesity levels in Europe (Health Improvement Analytical Team and Unit, 2010).
- More than 24% of the adult population of England is now obese (Health Improvement Analytical Team and Unit, 2010).

- The estimated costs to the economy from physical inactivity are £8.2 billion annually - this includes direct costs to the NHS and the indirect costs of lost days at work. It does not include the contribution of inactivity to obesity, which is estimated and £2.5 billion annually[68] (Chief Medical Officer, 2004).
- Reducing the proportion of insufficiently active people by just 5% could theoretically save £500 million[69] (Chief Medical Officer, 2004).
- The most affluent 20% of wards in England have five times the amount of parks or general greenspace (excluding gardens) than the most deprived 10% of wards. Areas which are more than 98% white in England have 6 times as many parks as wards which are 40% non-white[70] (CABE Space, 2010).
- It is estimated that by 2050 60% of adult men, 50% of adult women and 25% of children under 16 could be obese and that this would cost the NHS £10 billion a year and wider society £49.9 billion a year[71] (Foresight, 2007).
- An **ILLUSTRATIVE** cost benefit analysis of Natural England's expanded Walking for Health Scheme found that it would deliver 2817 Quality Adjusted Life Years (QALYs) at a cost of £4008.98 per QALY. An intervention must deliver health benefits for less than £30,000 per QALY to be judged cost effective by the National Institute of Clinical Excellence. The scheme is estimated to save the NHS £81 million and have a cost benefit ratio of 1:7.18[72] (Natural England, 2009b).
- Research suggests that when people have good access to greenspace (perceived and/or actual) they are 24% more likely to by physical active. Using this figure it is possible to generate an **ILLUSTRATIVE** cost saving covering the hypothetical benefit of moving from a situation of nobody having access to greenspace to everybody having access to greenspace of £2.1 billion[73] (Natural England, 2009a).

---

[61] The assumed causal relationship here is that better access to walkable greenspace led to increased exercise, but this causation pathway is not demonstrated by the research. The study controlled for age, marital status, baseline functional status and socioeconomic status. The study points out that the relationship for greenspace holds best for urban areas, but less well for car dependent suburbs.
[62] This study found that only 6 per cent of residents reported using a health club for exercise, which highlights the importance of parks to poorer communities who may not be able to afford access fees. The study relates park facilities to demographic groupings and has an appropriate stratified random sampling model. However, it reports no controls which limits its ability to draw causal conclusions. It should therefore be read as offering strong circumstantial evidence.
[63] The study controlled for housing condition, employment, level of education, ownership to dwelling, age, gender, household type, second home and bicycling for work.
[64] This study considered both distance to and quality of local greenspaces, and found no significant relationship with activity levels, even when level of deprivation and car ownership was controlled for.
[65] This study used a survey response and GIS coding to consider distances to greenspace. Results are controlled for age, sex, socio-economic status, self-rated health, and area deprivation.
[66] This calculation was additionally controlled for the walk-ability of the neighbourhood using information about the road layout.
[67] Children need at least 60 minutes a day of moderate exercise, at least twice a week they need more intense exercise which puts significant stress on bones and muscles.
[68] This includes costs to the economy as well as to the NHS. The £8.2 billion figure is taken from Department for Culture, Media and Sport/Strategy Unit. Game Plan: a strategy for delivering Government's sport and physical activity objectives. London: Strategy Unit, 2002, which has not been reviewed for this evidence package. The £2.5 billion figure is taken from National Audit Office. Tackling obesity in England. London: The Stationery Office, 2001, which has not been reviewed. £0.5 billion of this is direct cost to the NHS and £2 billion is wider cost of the economy.
[69] This is taken from Department for Culture, Media and Sport/Strategy Unit. Game Plan: a strategy for delivering Government's sport and physical activity objectives. London: Strategy Unit, 2002. Not reviewed.
[70] This document contains much more detail about park usage and satisfaction in England.
[71] Figures at 2007 prices.

[72] These figures are based on an illustrative cost benefit analysis which is built up from reasonable assumptions as to the way the scheme is designed to work. It does not include all the costs as data are not available for the non-Natural England contributions. However, the assumptions are conservative and the conclusion that the walks represent value for money is extremely robust.

[73] This savings figure is based on an academically peer-reviewed cohort study in Japan, with appropriate controls including age, sex, smoking, alcohol, body mass index, participation in sports activities, self-rate health, and history of hypertension, diabetes, cancer, liver disease or renal disease - (study details (Tsuji *et al*., 2003) This study is therefore of high-quality and the only significant issue is the comparability between health care costs with the UK, but as it is a developed country it seems a reasonable transfer. It also uses evidence from (Jones *et al*., 2010) which found that people were 24% more likely to meet physical activity recommendations with access to greenspace. This is also a high-quality peer-reviewed study with appropriate controls, but its findings are at odds with other equally high quality studies (see above) so this must be understood when using the resulting numbers.

Community cohesion

Introduction

4.24 Local authorities and governments generally are keen to promote community cohesion and social capital. There is some evidence which suggests that investment in green infrastructure can have a positive impact on these qualities, and other evidence which suggests that community cohesion can improve crime rates and health and educational outcomes. In principle some of these benefits can be valued economically.

Logic chain

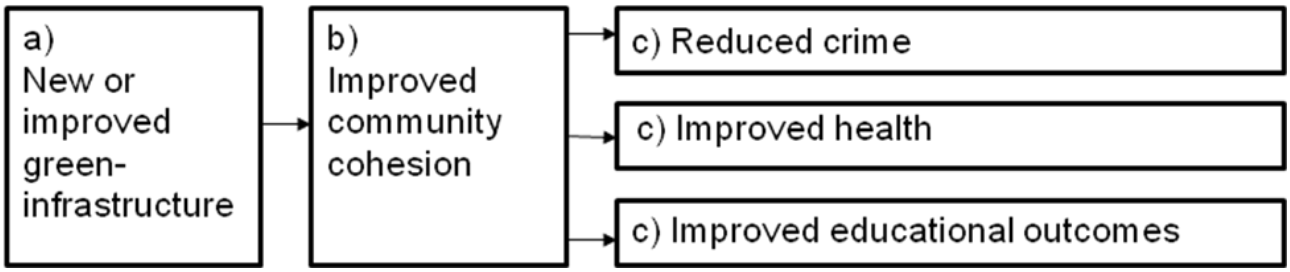

Figure 9

Can the benefit be quantified?

4.25 Only extremely tenuously. There is as yet no agreed measure of community cohesion, although there are indicators which point to its strength or weakness. This benefit is therefore likely to remain qualitative. The closest to quantification which is in use is a monetisation of volunteer hours; this is not really a measure of community cohesion but is likely to remain the best available proxy for some time.

How strong is the evidence?

4.26 We begin with evidence linking boxes a and b. Although park spaces can be unhelpfully dominated by one ethnic group leading to exclusion and inter-community tension, Gobster reports evidence from Chicago that suggests that parks can be active agents promoting inter-community relations in a way which is almost unique in urban life (Gobster, 1998).

4.27 There is a peer-reviewed study based in a deprived part of Chicago which finds that both property crime and violent crime are reduced significantly by the presence of vegetation. The authors hypothesise that the vegetation increases positive social interaction, hence increasing surveillance and has a calming effect. (This means that it links two ends of the logic chain with increased social cohesion one of two hypothesised causes in the middle). It is important to note that the vegetation was high canopy trees and grass, and therefore did not unhelpfully restrict visibility[74] (Kuo and Sullivan, 2001).

4.28 There is peer-reviewed evidence to suggest that social cohesion reduces crime, even when deprivation is controlled for (Hirschfield and Bowers, 1997). In principle, decrease in crime due to increased social cohesion can be monetised, and there are official values for the economic and social costs of crime (Home Office, 2003/04). However, it is not currently possible to make sufficiently convincing quantitative links to justify this.

4.29 There is peer-reviewed evidence which links social cohesion to health outcomes, based on a cross-sectional study comparing health outcomes with membership of voluntary groups and trust levels (Kawachi *et al*., 1997)[75]. However it is important to note that this study relates both indicators to income inequality - this is to say it posits a social rather than an environmental cause for the level of social cohesion. Health outcome benefits could be valued economically using official figures - interventions are considered cost effective if they cost less than £30,000 per

quality adjusted life year (Natural England, 2009b). However, it is not currently possible to make sufficiently convincing quantitative links to justify this.

---

[74] The study took place in a deprived social housing community in Chicago. The community was socially and ethnically homogenous, with homogenous housing stock and residents not able to select housing with more or less vegetation. The number of apartments per building, building height, vacancy rate and the number of occupied units per building were controlled for.
[75] This study controlled for absolute poverty levels.

4b: Regulatory services

4.30 This part of the chapter reviews the evidence for regulatory services. These are the ways in which nature regulates our environment which are often taken for granted, until they fail, when they can impose significant social and economic costs. In addition, to the evidence review on these pages, please note that the Environment Agency maintains a 'live' database of the current state and priority of research into flood risk and land use (Environment Agency).

Flood control - freshwater

Introduction

4.31 This section reviews the benefits green infrastructure offers in reducing flooding from rainwater, and the next section looks at **flood risk management at the coast**. Many of the interventions which will reduce flood risk have the potential to support water quality through reducing diffuse pollution and supporting water availability through water storage - see the **water purification and treatment** and **Freshwater** sections.

4.32 Futures research from the Government Office for Science and Technology found that continuing with existing flood control policies was not an option, because under virtually every scenario considered, risks rose unacceptably (Foresight, 2004). The landscape plays an important role in storing and distributing freshwater and its ability to do this can be weakened or enhanced by economic activity. Knowledge about likely flooding patterns can enable planning to mitigate these risks. Many economic activities impair water storage, but conversely there are opportunities to manage the environment in ways that improve it. Improved flood control leads to reduced costs of flooding and can by extension lead to reduced insurance premiums and increased property values[76]. In contrast to some other benefits reviewed in this package, it is an absolute benefit, ie the improvement does not have to be based on another area's loss.

Production chain

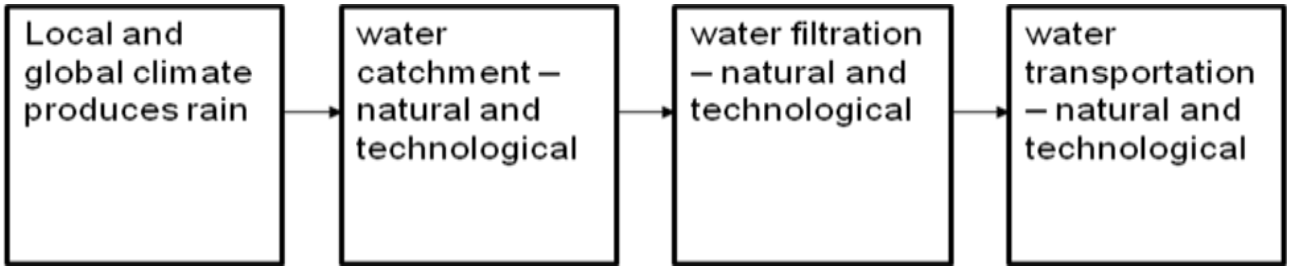

Figure 10

Proposition

4.33 There are changes we can make to land use and land management which will reduce flood risk.

Can the benefit be quantified?

4.34 In principle the relationships could be quantified, but the number of contextual factors means that there is currently, and is likely to remain, significant uncertainty around quantification for some time, not least to the wide variation in hydrology between water catchments.

How strong is the evidence?

4.35 Evidence about flooding is inherently complex and contextual and therefore strongly generic statements and formulas are not available. However, a review of the evidence yields important useful information:

Building on floodplains

4.36 Continued building on flood plains increases flood risk (Environment Agency, 2007) to the building themselves and also others downstream. Despite this 11% of new houses in England since 2000 have been built on floodplains[77] (Pitt, 2008).

Rural

4.37 Intensification of farming since the Second World War has led to a number of changes to the farmed environment which increase the rate of run-off. These include loss of hedgerows, overgrazing, channelised rivers, and winter crops leading to bare and compacted soil (O'Connell *et al*., 2005). Furthermore there is some evidence which supports a correlation between upstream soil damage and large floods. Holman *et al*. (2003) found significant soil degradation in the catchments which flooded in 2000 and suggest that flooding may be caused by a combination of soil degradation and prolonged wet weather. Additionally O'Connell *et al*. (2005) report that Boardman *et al*. (2003) found a statistically significant relationship between autumn sown cereals and local muddy floods. A general review of the causes of soil compaction place the emphasis on trafficking (mechanised vehicles) and to a lesser extent on stocking levels, particularly when fields are wet (ADAS, 2008).

4.38 Many blanket bogs have been drained through the cutting of drainage 'grips'. This degrades the bog, increasing emissions of CO_2. Reblocking these grips rewets the blanket bog slowing run-off from the uplands[78] (EFTEC, 2009).

4.39 There are good opportunities to reduce run-off from farms through measures such as grass buffers, temporary ponds, appropriate ditching and decanalisation[79] (O'Connell *et al*., 2005). Although there is no proven rule that organic and other less intensive forms of farming will always reduce flood risk, in general terms less intensive farms have less of the factors which support faster run off. The few UK studies and those from abroad support the view that less intensive farming leads to reduced flood risk due to greater presence of the features above and healthier soil (O'Connell *et al*., 2005).

4.40 There are three ways in which trees may contribute to flood control. Firstly conifers use a great deal of water and increase the capacity of the soil to absorb water (Nisbet *et al*., in press). Secondly, through the higher infiltration rates of forest soils. Modelling since the O'Connell review in Pontebren in Wales suggest that **IN THIS CONTEXT** a shelterbelt at right angles to the slope can reduce field scale flood peaks by 40%[80] (Jackson *et al*., 2008). Thirdly, through greater hydraulic roughness of floodplains. Modelling around the river Parrett in South West England found that floodplain woodland could slow water velocity within the woodland increasing the water level by up to 270 mm and increasing flood storage by 71%. For the two areas modeled flood peak was slowed significantly - the water's travel time was increased by 30 and 140m[81] (Thomas and Nisbet, 2007). Therefore although the effects of forests are mixed and context specific (O'Connell *et al*., 2005) (see footnotes for some of the potential downsides) well planned planting has the potential to mitigate flood risk (Nisbet *et al*., in press).

4.41 Although it is logical that increased farm runoff and local flooding would feed into larger flood events there is as yet little direct evidence for it (O'Connell *et al*., 2005). This is because dealing with larger floods is made more complex because the key issue is the extent to which water from tributaries arrives at the vulnerable site at the same time, meaning that action which reduces local flooding could make a larger flood event worse (O'Connell *et al*., 2005). This means that some areas which shed water rapidly may be necessary to ensure flood waters reach the critical region out of phase. This is part of the reason why although local effects are well understood, there are currently no clear evidenced connections between local land management changes and large flood events. However, the scarcity of evidence in this area may be due to the inherent difficulties in this research challenge and the little amount of research which has been done at the appropriate scale (O'Connell *et al*., 2005). Whilst flood risk modelling is highly developed for existing catchments O'Connell *et al*. (2005) do not consider any of the current attempts to model effects of land management robust enough for policy making[82]. An Environment Agency whole catchment modelling project for the river Parret in Somerset concluded that, although other

measures could be beneficial, major rainstorm events would require significant detention of water at upstream locations (Park and Cluckie, 2006). (This would require new infrastructure which could be green, grey or a mixture, but positive impact on flood risk would require a catchment wide approach).

Urban

4.42 There have been significant problems in recent years with intra-urban flooding - in which the drainage systems within the urban area are overwhelmed by rainstorms (Parliamentary office of Science and Technology, 2007). These flood events have been made worse by changes to the urban realm such as increased hard landscaping and the paving of driveways (Parliamentary office of Science and Technology, 2007).

4.43 Sustainable Urban Drainage Systems (SUDS) cover a mixture of approaches which filter or retain water near where it lands offering flood protection and biodiversity benefit. Reviews have found these to be cost-effective flood control mechanisms (Duffy *et al*., 2008).

4.44 Green roofs intercept rain water and reduce peak run off. This is most effective for smaller storms but the effect is reduced for larger storms in which roofs become saturated. The effectiveness will vary according to type of roof and local climatic conditions (Mentens *et al*., 2006).

4.45 Urban forests intercept rain water and reduce peak run off. This is most effective for smaller storms but the effect is reduced for larger storms in which canopies become saturated. The effectiveness will vary according to local climate, tree species and time of year (broadleaved trees have no leaves during winter storms) (Xiao *et al*., 1998).

Link with Climate Change

4.46 The problem of rain water floods is likely to have already been exacerbated by climate change because all regions of the UK have experienced an increase in the amount of winter rain that falls in heavy downpours (DEFRA, 2009). For all regions an increase in winter rainfall and a decrease in summer rainfall is projected by the 2040s. Winter rainfall in the Northwest of England is projected to increase by 6% in the 2020s, 10% in 2040s, and 16% in the 2080s[83] increasing flood risk (DEFRA, 2009). Climate change may also lead to reduced soil organic content (Jenkinson *et al*., 1991), which would exacerbate flood risk. This makes climate change mitigation a key action in reducing flood risk. It also means that better flood management will be required in the future and some climate change is already 'locked in'.

Examples and figures

- The UK spends £800 million per year on flood defences and suffers an average of £1,400 million in damage, making the total cost of flooding £2.2 billion per year (Foresight, 2004).
- The 2007 summer floods were the country's largest peace time emergency since World War Two, leading to expected insurance industry pay outs of £3 billion (Pitt, 2008).
- It is estimated that agriculture makes flooding worse by £234 million annually[84] (Jacobs, 2008).
- On the 20th July 2007 Gloucestershire received one and a half times the average monthly rainfall for the whole of July in one day, leading to £50 million damage costs, including £25 million repair bill for highways and £2.4 million for schools. The County Council have since invested £0.8 million in a district council land drainage project and £0.6 million in Environment Agency flood alleviation projects (DEFRA, 2009).
- The Association of British Insurers note that claims from storm and flood damage in the UK doubled to over 6 billion over the period 1998 - 2003 with the prospect of a further tripling by 2050 (DEFRA, 2009).

- Modelling conducted on Manchester found that adding green roofs to all buildings in town centres, retail and high-density residential could reduce run off by 17.0 - 19.9% (Gill *et al*., 2007).
- Being flooded significantly increases the risk of both physical illnesses such as gastroenteritis and mental ill health (Tunstall *et al*., 2006). Reacher (2004) found that adults who had suffered from flooding had four times the background level of psychological distress.
- Research in Scotland found sustainable urban drainage systems (SUDS) were a cost-effective method of delivering drainage which met the requirements of current environmental legislation. The term SUDS covers a mixture of interventions but normally include detaining water above ground close to where it fell, as in this case. In particular capital costs of traditional drainage are more than double the capital costs of SUDS, annual maintenance costs are 20 - 25% cheaper for SUDS and SUDS is around half the cost over a 60 year life span[85] (Duffy *et al*., 2008).

---

[76] See 'House Prices - proximity effects' to put this in economic context.
[77] This figure is contained in the Pitt Review but it is referenced to House of Commons Communities and Local Government Committee, Planning gain supplement (London: Stationery Office, 2006), HC 1024.
[78] This presentation provides evidence of the wider effects of grip blocking.
http://www.blanketbogswales.org/userfiles/file/Binder1.pdf
[79] Although the literature is insistent that application must consider the context in every case.
[80] The context is hillsides in Wales which are heavily stocked with sheep, have heavy (not very permeable) clay soils and significant artificial drainage. The results are for a significant row of trees (80m x 15m). These results are based on a comparison between modeled data and field results.
[81] This effect is supported by an independent modeling in Australia (Anderson *et al*., 2006). This study is based on small scale modeling and concludes that significant benefits could be available if the approach was scaled up. This brings it into tension with a Whole Catchment Modeling Project for the same river which found that whilst new forestry could make a difference but that very significant areas would be need to be given over to woodland to make an impact (Park and Cluckie, 2006) Another potential downside is that the presence of large Other concerns to be considered before planting new floodplain woodland are the potential to the backing-up water to threaten properties, the need to avoid interfering with engineered flood defences which are designed for fast flows to relieve flood risk, and ensuring the woodland does not take too much water from the system and therefore become environmentally damaging (Nisbet *et al*., in press)
[82] Note that research is currently underway involving the Environment Agency and the University of Durham, with Natural England inputting into the steering group.
[83] These figures are taken from DEFRA's climate change adaptation report and based on the world's leading climate change models. The baseline is 1961 - 1990 meaning that some of the climate change projected has already occurred. They are based on the central scenario which is effectively business as usual for global fossil fuel emissions. These figures function as an example of other regional figures which are available from **http://ukcp09.defra.gov.uk**
[84] This assessment is based on an environment agency judgement based on their record that 14% of flood damage is attributable to agriculture - this will almost certainly be an understatement because it is based only on hill-slope flooding. On this basis 14% of the damage caused by flood and the money spent to prevent floods is attributed to agriculture.
[85] The study methodology is robust and conservative and the figures inputted are based on real costs. The major cost omitted from the study is the cost of the (surface) land taken up by SUDS, but this is clearly flagged. On the other side of the balance sheet however, the traditional engineering system which serves as a cost comparison would require additional treatment to meet regulatory standards and this cost was not included. Neither where the aesthetic and biodiversity benefits of the SUDS system. A full blown cost-benefit analysis which included these would be useful, but this study is a useful comparison of engineering and maintenance costs. The study does not appear to use Green Book standard discount rate because it applies the standard 3.5 per cent for the full 60 years of its life time costs analysis, and this should drop to 3 per cent for the second 30 years, but this will not significantly alter the findings. The study was paid for by the developers of the site (Taylor Wimpey Developments Ltd), but this is clearly marked and it's a reputable peer-referenced journal.

Flood risk management at the coast

Introduction

4.47 This section reviews the evidence for flood risk management at the coast, which is part of coastal defence[86]. Flood control from rainwater is in the **previous section**. Futures research from the Government Office for Science and Technology found that continuing with existing flood control policies was not an option, because under virtually every scenario considered risks rose unacceptably (Foresight, 2004). The managed re-alignment approach, in which new inter-tidal habitat is created can have benefits for flood risk management, as fish nurseries and as visitor attractions due to their biodiversity value.

Proposition

4.48 There are changes we can make to land use and land management which will reduce flood risk.

Can the benefit be quantified?

4.49 The economic figures which are normally offered relate to costs of engineering for coastal defence, and these can be quantified within reasonable error margins. The costs of flooding can also be quantified, but there is more likely to be disagreement about these estimates, particularly when they include wellbeing loss (economic **VALUE**) as well as direct economic loss (**IMPACT**).

How strong is the evidence?

4.50 Salt marshes act an important natural form of sea defence, dissipating wave energy before it reaches the sea wall or other infrastructure/high ground behind it. However many salt marshes have been lost due to 'coastal squeeze' where they are trapped between rising sea levels and hard man-made sea defences. Intertidal habitat recreation therefore has a major contribution to make to cost effective flood defence at the coast; as does the conservation of, and allowing 'natural roll back' of, existing saltmarshes[87] (Collins *et al*., 1997).

Examples and figures

- It has been estimated that an 80m wide zone of inter-tidal habitat fronting sea walls can save £4,600 per m in sea defence costs[88] (Collins *et al*., 1997).
- Alkborough Flats is a managed re-alignment scheme on the south side of the river Humber. The sea wall was deliberately breached to allow both permanent and irregular flooding of former farmland. The Environment Agency's project appraisal report assessed the flood defence benefit as worth £12.26 million based on a time period of 100 years leading to a cost benefit ratio of 1:2.72. Further work which sought to quantify the other benefits of the scheme, particularly provision of habitat raise the cost benefit ratio to 1:3.22[89] (Everad, 2009).
- Modeling of the potential benefits of the adoption of a managed re-alignment approach to the Blackwater Estuary in Essex was undertaken. It found that the approach would reduce the maintenance costs of flood defenses, significantly reduce nutrient discharge into the North Sea (reducing the eutrophication risk) and create important wetland habitat. Under very conservative assumptions the scheme was cost-beneficial over a 100 year time frame (Shepherd *et al*., 2007)[90].
- A second entirely separate modeling of the potential benefits of the Blackwater Estuary in Essex was also undertaken, but this one undertook a bespoke willingness-to-pay study for the habitat creation. The study identified reduced cost of developing hard defenses, the value of the new habitats as fish nurseries, carbon sequestration, and the composite value of the new habitat (covering amenity, recreation and biodiversity). The study found benefits of £100 million after 25 years of following increased use of management re-alignment, where the level of re-alignment was designed to combine economic growth and environmental protection (Luisetti *et al*., 2008)[91].
- Modelling on the Humber Estuary found that a whole estuary managed re-alignment approach led to a benefit to society of £4.4 million over a 50 year time frame and £10.8 million

over a 100 year time frame. These calculations are based on values for the habitat created, plus avoided carbon emissions, but do not take into account reduced cost of sea all building and maintenance, with which they would be greater (Turner *et al*.)[92].

Connection with climate change

- Sea levels have risen by 1mm a year during the 20th century (DEFRA, 2009).
- Sea level is projected to rise by 18cm in London by 2040 and 36cm by 2080[93] (DEFRA, 2009).

---

[86] Coastal defense is a broader term which includes erosion risk as well - this is not covered in this first edition of the review.
[87] This evidence is taken from a joint Environment Agency, English Nature, Cambridge Coastal Research Unit and contains academic references which have not been reviewed for this evidence package.
[88] This evidence is taken from a joint Environment Agency, English Nature, Cambridge Coastal Research Unit and contains academic references which have not been reviewed for this evidence package.
[89] I have not reviewed the Environment Agency project report on which the flood defense figure is taken, but as the official report of a major infrastructure project I am confident it will be to Green Book standards. The flood defense figure cited is a net present value figure with future year's benefits discounted according to Green Book standards. The wider ecosystem service valuation is experimental in that it pushes the edges in finding values for things that would normally be considered too difficult and contains a number of very strong (ie questionable assumptions). However assumptions are all clearly spelt out, and none of the strong assumptions make a material difference to the cost benefit ratio. Additionally the approach taken is appropriately conservative and so I have no hesitation in recommending the use of the ratio.
[90] The cost benefits analysis is constructed extremely conservatively, it is therefore likely that a realignment approach would be cost-beneficial on a much shorter time frame. For example, the costs of new secondary defences are included as part of the realignment scenario, but might not be needed. Furthermore a very conservative price for carbon (£7 per tonne) is used by today's standards. The nutrient capture function and the habitat creation function of the project are not counted independently to avoid risk of double-counting. The study also doesn't take account of the global warning effect of the N_2O. The study includes a value for the habitat creation which is transferred from other literature and not reviewed (however it is important to note that a separate study which conducted a bespoke willingness to pay study for the value of habitat creation on the Blackwater estuary also finds managed re-alignment strongly beneficial see the Luisetti study in the next bullet point).
[91] The figure quote relates to the Net Present Value of the 'Policy Targets' level of managed re-alignment over a 25 year timeframe at the official treasury discount rate. This figure increases to £221 million over 50 years and £444 million over 100 years, which is a reasonable time-frame for this sort of infrastructure. The analysis also shows that greater benefits would derive from higher levels of managed re-alignment. Note that this benefit does not include the cost saving from not maintaining the traditional infrastructure which would add another £1.2 million. The big advantage of this study is that that values for habitat gains a based on a new bespoke choice experiment study which was well designed, including concerns about size and quality of the habitat and distance from the respondents home.
[92] The figure quoted is the difference between the Net Present Value of 'Hold the line' level which assumes no re-alignment and the 'Policy Targets' level in which economic growth is combined with environmental protection at the official treasury discount rate. The analysis also shows that greater benefits would derive from higher levels of managed re-alignment. The value for habitats driving this analysis is based on transfer from a meta-analysis of studies which value wetlands, which is the most robust way to derive a value without a new willingness-to-pay study. A figure of £7 per tonne of carbon was used, which is low by contemporary standards, and the use of contemporary figures would increase the value of the project.
[93] These figures are taken from DEFRA's climate change adaptation report and based on the world's leading climate change models. The baseline is 1961 - 1990 meaning that some of the climate change projected has already occurred. They are based on the central scenario which is effectively business as usual for global fossil fuel emissions. These figures function as an example of other regional figures which are available from **http://ukcp09.defra.gov.uk**. The most extreme scenario considered, but not considered likely was at 1.9 metre sea level rise by 2100.

Water purification and treatment

Introduction

4.51 Clean healthy water is a central human environmental dependency and is important for the wider health of the natural environment. Currently the majority of water bodies in the UK fail to meet the target of good ecological and chemical status (Nisbet *et al*., in press). This section contains evidence relating to the environment's contribution to purifying water. The freshwater section provides evidence about the amount of freshwater available.

Production chain

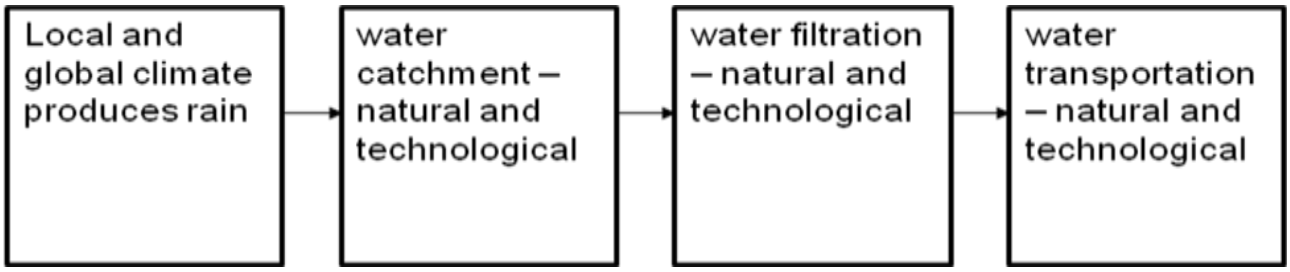

Figure 11

Proposition

4.52 Green Infrastructure interventions can contribute to purifying and treating waste water.

How strong is the evidence?

Rural

4.53 There is strong evidence to support woodland creation, in appropriate locations, to achieve water management and water quality objectives[94]. Woodland's contribute to tackling diffuse pollution through acting as a barrier and intercepting pollutants before they reach water courses. They help to trap and retain nutrients and sediment in polluted runoff (Nisbet *et al*., in press). Targeted woodland buffers along mid-slope or down-slope field edges, or on infiltration basins, appear effective for slowing down runoff and intercepting sediment and nutrients, but the evidence base is limited (Nisbet *et al*., in press). Restored as well as mature buffer zones can be effective (Vellidis *et al*., 2002). They are most effective when the runoff water must pass through the root zone, and least effective where rivers are recharged significantly from groundwater (Lowrance *et al*., 1997). Short rotation coppice has the potential to provide timber with low average nitrate losses[95] (Nisbet *et al*., in press).

4.54 Wider targeted woodland planting in the landscape can reduce fertiliser and pesticide loss into water, as well as protecting the soil from regular disturbance and so reduce the risk of sediment delivery to watercourses.

4.55 There is good evidence that wetlands bordering rivers are an effective method of preventing non-point source pollutants from entering surface water. Ref Gilliam[96] (1994) for Nitrogen and Phosphorous and Gambrell (1994) for metals.

4.56 Many blanket bogs have been drained through the cutting of drainage 'grips'. This degrades the bog, increasing emissions of CO_2. Reblocking these grips rewets the blanket bog. This is expected to lead to reduced sediment and reduced colouration of the water, but there is as yet a shortage of quantitative data[97] (EFTEC, 2009).

Urban

4.57 Polluted run-off from urban drains is a major cause of diffuse pollution (Hatt *et al*., 2008).

4.58 Green roofs are most effective for the smaller more common storms, because they tend to become saturated during major storms. However, most of the diffuse pollution load entering the drains is from these more common storms, and so green roofs have an important role to play in reducing this (Mentens *et al*., 2006).

4.59 Urban forests intercept rain water and reduce peak run off. This is most effective for smaller storms, but the effect is reduced for larger storms in which canopies become saturated. However, most of the diffuse pollution load entering the drains is from these more common storms, and so urban forests have an important role to play in reducing this. The effectiveness will vary according to local climate, tree species and time of year (broadleaved trees have no leaves during winter storms) (Xiao *et al*., 1998).

4.60 Sand and soil based filters are an effective means of removing pollutants from urban runoff[98] (Hatt *et al*., 2008).

4.61 Sustainable Urban Drainage Systems, such as detention pools, are an effective method of removing pollutants from water and do not collect levels of pollutants which would require notified disposal (Heal *et al*., 2006, Napier *et al*., 2009).

4.62 Any measures which increase rainwater infiltration (Parliamentary office of Science and Technology, 2007) are likely to reduce the number of occasions under which sewerage systems are overwhelmed by large volumes of water with resultant water quality issues (Environment Agency, 2007).

Connection with climate change

4.63 All regions of the UK have experienced an increase in the amount of winter rain that falls in heavy downpours (DEFRA, 2009). For all regions an increase in winter rainfall and a decrease in summer rainfall is projected by the 2040s. Winter rainfall in the Northwest of England is projected to increase by 6% in the 2020s, 10% in 2040s, and 16% in the 2080s[99] increasing risk of polluted run-off (DEFRA, 2009). This makes climate change mitigation a key action to prevent diffuse pollution becoming worse. But because a significant amount of climate change is already 'locked in' it also means that these green infrastructure interventions will be increasingly important in coming decades.

Link with climate change

4.64 Climate change is likely to lead to increased use of pesticides (Boxall *et al*., 2010). Nutrient inputs may decrease, however increased temperature, reduced summer rainfall, and increased winter rainfall and the increased use of irrigation may increase transmission leading to increased water pollution (Boxall *et al*., 2010). Climate change may also reduce soil organic content (Jenkinson *et al*., 1991), which would exacerbate problems of polluted runoff. Without mitigating action this would increase human exposure to agricultural contaminants (Boxall *et al*., 2010).

Examples and figures

Rural

- It is estimated that the annual cost of agricultural diffuse pollution in the UK is at least £238.11 million[100] (Jacobs, 2008).
- 90% of ground water bodies in England and Wales are at risk, or probably at risk, from failing to meet good ecological status targets due to diffuse pollution washed by rainfall from the land into groundwater[101] (Environment Agency, 2008a).
- The Sustainable Catchment Management Programme (SCaMP) aims to tackle habitat issues and address some water quality issues on a catchment wide basis. The project covers around 20,000 ha of land owned by water company United Utilities and helps to supply some of the company's 7 million customers with their daily water needs. The programme has already restored or secured around 13500 ha of Sites of Special Scientific Interest (SSSI) into

favourable or recovering condition. Although the focus is primarily on restoring habitats and enhancing biodiversity, water quality benefits are also expected in the long-term. It is hoped that by restoring degraded moorland catchment areas the current increasing water colour will stabilise in the future (Natural England, 2009c).

- In order to meet its drinking water requirements under the US Safe Drinking Water act, New York City opted to seek a waiver on the filtration requirement by investing in a comprehensive watershed protection programme in the Catskills-Delaware watershed, which supplied 90% of the city's drinking water. New York spent $1.5 billion over 10 years to avoid $6 billion in capital costs and $300 million annual operating costs[102] (Postel and Thompson Jr, 2005).
- Research into ecological improvements to the river Elbe in Germany concluded that restoring 15,000 hectares of wetland would prevent pollutant nitrogen entering sensitive watercourses, providing a benefit of between 6.9 and 20.5 million Euros. When combined with estimates of the wildlife benefit from willingness to pay surveys this led to a benefit: cost ratio for the proposed intervention of between 2.5:1 and 4.2:1[103] (Meyerhoff and Dehnhardt, 2007).

Urban

- Environmental damage due to pollutants from urban diffuse pollution has been estimated at between £150 million and £250 million[104] (Environment Agency, 2007).
- In 2010 New York City published a plan to improve water quality in the New York Harbor System through reducing Combined Sewer Outflows following storms. The approach aims to use green infrastructure approaches (such as street trees, swales, bioinfiltration, and blue and green roofs), to capture first inch of rainfall on 10% of the impervious area in combined sewer watersheds over 20 years. It is estimated that this will reduce combined sewer overflows by 1.5 billion gallons a year. The report estimates that a mixture of green and grey infrastructure will allow it to meet its objectives for $5.3 billion as opposed to a purely grey strategy costing $6.8 billion[105] (NYC Environmental protection, 2010). Similar problems are faced in London; every year 12 million tonnes of untreated sewage enter the Thames because of storm overflows, with discharges 50 - 60 times a year. In August 2004, heavy rainfall led to pollution events that killed tens of thousands of fish, left sewage debris and significantly increased E. Coli levels and so enteric disease[106] (Environment Agency, 2007).

---

[94] However the Forest and Water guidelines advise against using conifer woodland in nitrate vulnerable zones with less that 650mm annual rainfall - they evaporate so much water they can concentrate the nitrogen (Nisbet *et al*., in press).

[95] Although losses of nitrogen may be high in the establishment and removal years.

[96] This is based on research conducted in the United States. The author quotes studies pointing to 90% effectiveness for nitrogen and 50% for Phosphorous. The author states that wetland by rivers is, in his view, the most important method influencing non-point source pollutants entering surface water in many parts of the US.

[97] This presentation provides evidence of the wider effects of grip blocking **http://www.blanketbogswales.org/userfiles/file/Binder1.pdf**

[98] This study found leaching of Phosphorous but suggested that it was probably native to the soil used, rather than a failure of the filter to capture pollution from the runoff.

[99] These figures are taken from DEFRA's climate change adaptation report and based on the world's leading climate change models. The baseline is 1961 - 1990 meaning that some of the climate change projected has already occurred. They are based on the central scenario which is effectively business as usual for global fossil fuel emissions. These figures function as an example of other regional figures which are available from **http://ukcp09.defra.gov.uk**

[100] It is important to be clear that Green Infrastructure type interventions could mitigate, not remove this cost. This figure is an addition of two parts. The first part is figures given by Jacobs for lower water quality in rivers: £62 million, Lakes: £27 million, Coastal bathing water: £11.10 million and estuaries: £3.01 million. Separate figures are also available for England for all but lake eutrophication for which an England and Wales figure is available. The calculations are make on the basis of 'best available data' and reasonable assumptions and then the application of values from stated preference studies. The second section is estimates of the costs to the water industry of removing contaminants at £129 million annually for England and Wales (figure would be higher if Scotland and

Northern Ireland were included). This estimate is based on OFWAT data and reasonable assumptions of the percentage of the pollution that should be attributed to agriculture. Given the data available the approach is conservative and appropriate, and the 'true' value is probably considerably higher. The source research for the values applied has not been reviewed for this study.

[101] A map is available in the cited source **http://publications.environment-agency.gov.uk/pdf/GEHO1208BPAS-e-e.pdf**

[102] The provenance of these figures has not been checked back through the references, for this evidence package, but should be reliable because they are in a peer-referenced paper. Notice that just the annual operating costs of the filtration plant would cost more than the ecosystems approach, without the capital expenditure. The effectiveness of this programme is based on US Environmental Protection Agency continuing to grant the waiver on the filtration requirement, which may get more difficult as development in the Catskills-Delaware increases and stricter federal drinking water standards are introduced. The scheme has led to important economic, environmental and recreational benefits within the watershed, as well as the benefits to New York. It is important to note how different the context is from the UK though; more than three-quarters of the watershed is forested.

[103] Willingness-to-pay means that researchers assessed what customers would be willing to pay for that biodiversity benefit in a hypothetical market, this is a normal and accepted technique in environmental economics. The methodology was appropriate and conservative, but included a correction for embedding (a concern about whether people are valuing the right size of hypothetical good), not reviewed for this package in (Schulze *et al.*, 1998) It is important to note that the bulk of the benefit in the benefit:cost ratios is from the willingness to pay for biodiversity, rather than the nitrogen retention. A sensitivity analysis shows the benefit: cost ratio to be always above 1:1 even if you half the benefits or double the costs.

[104] This figure is taken from an Environment Agency response to a Royal Commission on Environmental Pollution consultation. However no reference is given so no further detail is available.

[105] Note that these are pre-project estimated costs, rather than project evaluation costs. Blue roofs are roofs that can hold water and release it after the storm surge. The Green Infrastructure approach also has the potential for some of the costs to be met by the private sector due to development standards. Other expected benefits of the Green Infrastructure approach are reduced urban heat island effect, energy conservation and carbon sequestration and improved air-quality. Higher property values are also cited, but see the section on property prices to put this in economic context.

[106] This figure is taken from an Environment Agency response to a Royal Commission on Environmental Pollution consultation. However no reference is given so no further detail is available. It is important to note that the majority of the solution to this is grey infrastructure.

Local climate regulation

Introduction

4.65 Temperature and humidity regulation of indoor and outdoor spaces is essential for human health and wellbeing. The Urban Heat Island effect, is caused by the large area of heat absorbing surfaces, high energy use and reduced wind speed (Bolund and Hunhammar, 1999) and leads to night-time temperature remaining high increasing human health risk (Kovats, 2008). Grey infrastructure solutions to this problem could make it worse - for example air conditioning pumps heat outside, increasing the outside temperature. This section reviews the evidence that green infrastructure can make an important contribution to this regulation, making outdoor spaces more livable and reducing the heating/cooling costs of indoor spaces. This benefit is of particular interest due to concerns about the Urban Heat Island effect, in which urban centres become significantly warmer than the surrounding countryside, particularly at night.

Production Chains

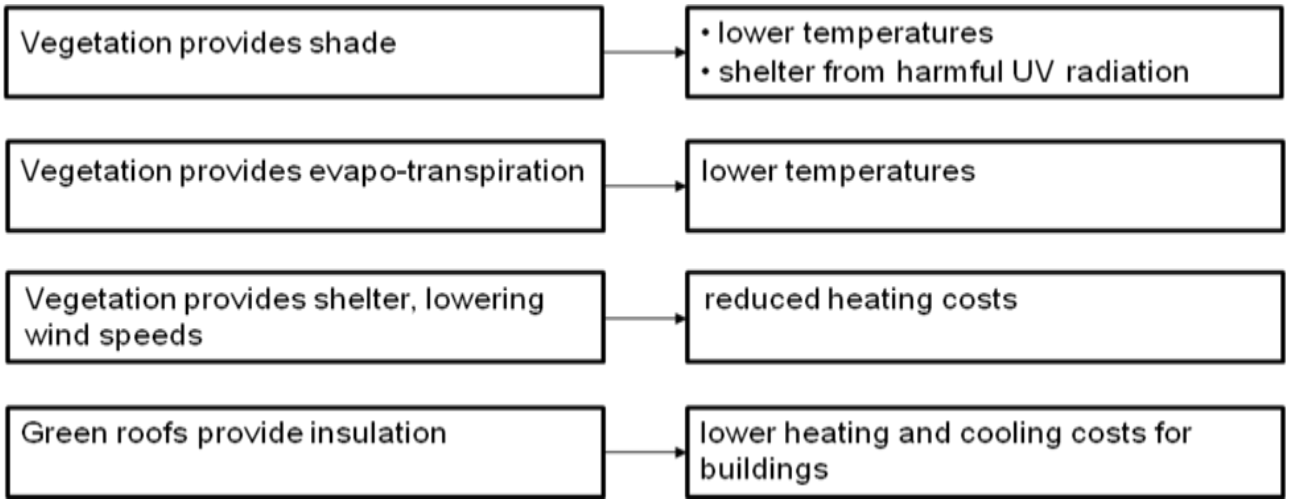

Figure 12

Proposition

4.66 Green Infrastructure can assist with the climate regulation of both indoor and outdoor spaces.

How strong is the evidence?

4.67 Green infrastructure makes a number of important contributions to local climate regulation. Watery areas can help to balance temperature deviations (Bolund and Hunhammar, 1999). A single large tree can transpire 450 litres of water in a day which uses 1000 Mega Joules of heat energy, making urban trees an effective way to reduce urban temperature (Bolund and Hunhammar, 1999). Urban parks are on average 1 degree cooler than built up areas during the day (Bowler *et al*., 2010a), but the type of park does matter - parks with hard paved surfaces and few trees or shrubs can be hotter (Chang *et al*., 2007). Green roofs act as effective insulators (Kumar and Kaushik, 2005), reducing the requirement for air-conditioning. Although in principle vegetative shading could reduce the risk from diseases caused by UV radiation very few studies have been done on the benefits of green infrastructure in this context (Bowler *et al*., 2010a).

4.68 Rising temperature in rural areas may also threaten valuable biodiversity, such as salmon and trout. An experiment in the New Forest found that river shading from new trees prevented water temperature from reaching the lethal limit for brown trout[107] (Nisbet *et al*., in press).

Link with climate change

4.69 It is projected that the average summer temperature in the South East of England will be 1.6 degrees warmer in the 2020s, 2.3 degrees warmer in the 2040, and 3.9 degrees warmer in the 2080s[108] (DEFRA, 2009). This will intensify the urban heat island effect.

Examples and figures

- The 2003 heat wave is estimated to have accounted for 600 extra deaths in London (Greater London Authority, 2006).
- By 2050 heat related deaths could increase to 2,800 a year (POST, 2004)[109].

---

[107] It is important however to note that conifer plantations, planted too close to stream sides can lead to bare stream banks and therefore increased erosion and siltation.
[108] This has been estimated by DEFRA based on comparison of world leading climate projection models. The warming is projected against a 1961-1990 baseline which means that some of it has already happened. These results are based on the central estimate which effectively assumes business as usual with regard to carbon emissions globally. This figure serves as an example, projections for other regions are available from **http://ukcp09.defra.gov.uk**.
[109] However, there could be a fall in winter related deaths of up to 20,000 cases a year.

Carbon sequestration

Introduction

4.70 Other sections of this review have highlighted the way in which green infrastructure can help us adapt to climate change, but the extent to which negative impacts can be adapted for is limited. This means that mitigation of climate change remains a policy challenge for central government. This section contains the evidence that investment in the environment can help us mitigate climate change, often at the same time as adapting to it.

Propositions

- New green infrastructure investment can remove greenhouse gases (GHGs) from the atmosphere and sequester them over the long-term.
- Current land use and land management patterns are leading to ecosystem degradation and the release of GHGs. Changing these patterns is therefore essential to meet GHG reduction targets.

Can the benefit be quantified?

4.71 Yes relationships can be quantified, but the science indicates that sequestration and emission rates are complex and context dependent. International transfer of economic values is facilitated by the fact that the social cost of carbon[110] is the same wherever it is emitted in the world, however some forms of pricing carbon, such as the UK non-traded price[111] are country specific.

How strong is the evidence?

4.72 There are major stores of carbon in land and sea ecosystems and therefore management of these is important. It is estimated that around 36.6 billion tonnes of potential CO_2 is stored in UK soils (Thompson, 2008). Currently Land Use, Land Use Change and Forestry is a small net sink for carbon, but is expected to revert to being a small net source by 2020 (Thompson, 2008). Peatlands contain the highest concentrations of stored carbon and degraded peatlands release between 2.8 and 5.8 million tonnes of carbon a year, making peat restoration a priority[112] (Thompson, 2008). A larger part of England's soil carbon is however stored in grassland and arable soils, due to the fact they are more extensive (Bradley *et al*., 2005).

4.73 UK Forests have a limited but important role in climate change mitigation. Global forests contain enough carbon to raise global temperature by 5-8 degrees, but UK forests only hold as much carbon as the UK emits in one year of fossil fuel burning. Additionally, carbon sequestered by forests is likely to be released when the trees decompose or are burned, although wood can sequester carbon over the medium to long term. Therefore there are number of roles for UK forests. Growth in forest cover will increase the amount of carbon held in biomass, but the affect is small compared to UK emissions. Additionally, wood fuel is carbon neutral and can substitute for fossil fuel, and through substitution for fossil fuel based products, particularly as a building material. Bringing neglected woodlands into management can potentially deliver significant benefits[113] (Broadmeadow and Mathews, 2003).

4.74 The UK's forest carbon sink reached a peak of 16 megatonnes of CO_2 per year in 2004, but has been dropping since due to a drop in the rate of planting and maturing of forest stands. An enhanced woodland creation programme involving planting 23,200 hectares could deliver abatement of approximately 15 megatonnes of CO_2 per year by the 2050s[114]; representing 10% of total emissions at that time (if we assume emissions have fallen as required by the Climate Change Act). Mixed woodlands for multiple objectives can deliver abatement at less than £25 per tonne of CO_2, which is significantly less than the £100 per tonne cost effectiveness threshold set by the Committee on Climate Change (Read *et al*., 2009).

4.75 Coastal and marine ecosystems are vital global carbon stores. Saltmarsh, in particular is important, and unlike the ocean's vast carbon stores which are beyond direct human

management, carbon storage and sequestration by salt marshes can be improved through management, including managed realignment of sea walls (Andrews *et al*., 2008).

4.76 There is however, an important research gap in evidence of the current scale of carbon storage and carbon management in many habitats (Thompson, 2008).

4.77 Ponds are frequently included in GI projects and may have an important role in sequestering carbon (Downing *et al*., 2008)[115].

Examples and figures

- It has been estimated that the UK's environmental stewardship schemes reduce emissions by between 0.44% and 0.49% of the 1990 Kyoto baseline over a 100 year time frame. This benefit is largely due to the move to less intensive land management - eg less fossil fuel inputs, less deep tillage, undercrops[116] (DEFRA, 2007c). This amounts to net savings of 1.0 million tonnes of CO_2 equivalent from Entry Level Stewardship (worth £53 million) and 4.1 million tonnes of CO_2 equivalent from Higher Level Stewardship (worth £211 million) with a combined total of 5.1 million tonnes of CO_2 equivalent (worth £264 million) (FERA, 2010).
- English peatlands are estimated to contain 2.14 billion tonnes of potential CO_2 emissions, roughly equivalent to 5 years of national emissions. Under current management English peatlands are responsible for emissions of approximately 3 million tonnes of CO_2 equivalent, about as much as is emitted by a third of a million British households. Peatland restoration could deliver emissions reductions of up to 2.4 million tonnes of CO_2 equivalent per year. At the central non-traded carbon price of £52 per tonne of CO_2 equivalent this is a benefit of £124.8 million (Natural England, 2010).
- It is estimated that land use change in England contributes significantly to net carbon emissions, which are valued at £839 million[117] (Jacobs, 2008).
- It is estimated that 31% of the EU's greenhouse gas emissions are associated with the food system (Foresight, 2011).
- The woodfuel strategy for England sets a target of bringing 2 million tonnes of woodfuel to market annually, entirely from un-harvested material available in English woodlands. It estimates that this would save 400,000 tonnes of fossil fuel carbon and supply 250,000 homes with energy (Defra, 2007d).

---

[110] Pricing carbon emissions is an attempt to include the damage done by carbon within our rational economic decision making framework. It is both difficult and controversial. The social cost of carbon is an attempt to work out the cost of the damage done by each cost of carbon. In contrast the non-traded price is based on the costs imposed on the economy by emitting that tonne of carbon given the UK's climate change reduction commitments (ie mitigation cost). It is called the non-traded price because it is used for sectors outside the European Carbon Trading mechanism.
[111] See endnote 108.
[112] This figure is based only on figures from lowland fens, so the actual figures will be larger. The complicating factor is that healthy peat bogs emit methane. More research is needed in this area but the balance of probabilities is that is that peatland restoration will be carbon beneficial.
[113] Forest soils can contain more carbon than that in the trees for two reasons. Firstly much of the Scottish plantations were planted on upland soils already rich in organic matter, secondly leaf litter increases soil organic content over time. Understory plants may also contain significant carbon. UK forests contain about 150 megatonnes of carbon. Interestingly, 80 megatonnes is contained in deadwood products, mostly imported from abroad.
[114] The 23,200 ha per year is based on 14,840 ha of additional planting per year on top of the assumed ongoing 8360 ha. Benefits seem to refer to the 23,300 ha per year figure.
[115] This peer-reviewed research was conducted in Iowa, a state with very intensive agricultural production. It found that eutrophic impoundment ponds were very effective at impounding organic carbon, with rates up to 17 kg of carbon per square metre per year and a median of 2.1 kg of carbon per square metre. Rates were highest in the

smaller impoundments pools and with larger watersheds. If this research is representative and estimates of farm pond usage worldwide are correct then the world's farm pounds may bury more organic carbon than the oceans.

[116] These figures do not take into account displacement of food production, either within the UK, or overseas, which could radically change the outcome. This points to the need to consider demand for food products as well as production methods. The results also assume no reversion to previous practices, and reversion is quite likely when the current schemes come to an end, suggesting we need to consider countryside management over a longer timeframe.

[117] Figures are calculated according to the Greenhouse Gas Inventories for England and then multiplied by DECC's official non-traded price of carbon. The main changes driving the emissions are application of lime to cropland and grassland, past drainage of peatland, conversion of land to cropland and grassland. However, this is likely to be a slight overestimate because carbon negative (ie, helpful) land use change has not been considered.

Air-quality

Introduction

4.78 This section reviews the evidence that green infrastructure can improve air-quality, and also considers the evidence that some types of green infrastructure can have negative effects on air-quality. There is a clear link with **local climate regulation** section, because some air-quality problems are worse at high temperatures.

4.79 Although air-quality has been improving significantly, this trend is flattening or even reversing in some areas (Tiwary *et al*., 2009) and it remains a significant problem, particularly in urban areas. In particular ozone levels have not decreased to the same extent and continue to fluctuate (Sustainable Development Commission, 2008). Areas with high NOx concentrations (which are mostly urban and suburban) are likely to see increases in ozone levels. Research in Europe suggests that transport related air pollution contributes to increased risk of mortality, heart-attack, lung cancer, allergic responses and acute asthma attacks in children. Initial estimates suggest transport related air pollution leads to tens of thousands of deaths in Europe, similar to the number caused by traffic accidents (Krzyanowski *et al*., 2005). Ozone can also have harmful effects on plant communities.

Proposition

4.80 Green Infrastructure can help to improve air-quality.

Can the benefit be quantified?

4.81 Yes, the relationships can be quantified but the exact effects will be influenced by local contextual factors. Therefore modeling relies on reasonable average assumptions.

How strong is the evidence?

4.82 NO_2 and PM_{10} concentrations tend to be highest in urban areas and higher relative concentrations are observed in the most deprived areas. Air-quality Management Areas are disproportionately deprived compared to the rest of the population[118] (AEAT, 2006).

4.83 Research has shown that vegetation reduces air pollution, but that the strength of the effect depends importantly on the vegetation and the context. Coniferous trees offer advantages due to their larger leaf area and remaining in leaf all year round, but broadleaved trees are better at absorbing gases. Thinner vegetation may filter air more effectively than thick vegetation which may instead form a barrier (Bolund and Hunhammar, 1999)[119].

4.84 Some trees release Volatile Organic Compounds, which reduces air quality. However, they also intercept ultraviolet light, reduce temperature through shading and remove pollutants through dry deposition. Modeling study from the North East of the United States found that urban forests will on balance reduce ozone pollution[120] (Nowak *et al*., 2000).

4.85 Research in the US has found that increased tree density in New York is associated with reduced levels of childhood asthma in a statistically significant manner, however it is not at all clear why this is the case, or whether it is to do with green infrastructure[121] (Lovasi *et al*., 2008).

Link with climate change

4.86 Higher temperatures lead to an earlier start and an increase of length and intensity of the pollen season (D'Amato and Cecchi, 2008). They also lead to increased pollutant levels and increased long distance transportation of pollutants and increased heavy precipitation events (which are associated with significant increased asthma) (D'Amato and Cecchi, 2008). Additionally high temperatures may promote the formation of ozone (USEPA, 2010). With constant emissions levels this can be expected to lead to increased illness and premature deaths (Ebi and McGregor, 2009). The combination of climate change, the urban heat island effect and air pollution therefore represent a significant challenge to healthy livable cities. However, warming temperatures could

also lead to reduced susceptibility to upper respiratory infections due to warmer winters (D'Amato and Cecchi, 2008).

Examples and figures

- The UK air-quality strategy estimates that air pollution reduces the average life expectancy by 7 - 8 months and that this equates to a cost of £20 billion a year[122] (DEFRA, 2007a).
- Modeling found that 547 ha. of mixed greenspace within a 10 x 10 km square of East London (ie 5% of 100 square kilometres) could significantly reduce pollution with an estimated effect of two deaths and two hospital emissions avoided per year[123] (Tiwary *et al*., 2009).
- Modeling of removal of pollution by trees across the urban areas of the United States estimated that they remove 711,000 tonnes of pollution from the air per year with an economic value of $3.8 billion. This could be increased through increasing the density of tree cover - with 100% tree cover providing 16% improvement in 0_3 and SO_2, 9% for NO_2 and 8% of PM_{10} are possible in an hour[124] (Nowak *et al*., 2006).
- 1.1 million children in the UK are currently being treated for Asthma (Asthma UK, 2010).

---

[118] A complicating factor is that urban centres also contain some of the wealthiest communities in England, whereas rural areas have more middle-income populations. Therefore the relationship between deprivation and air-quality is U-shaped, not linear.

[119] This information is taken from Bolund and Hunhammer's peer-reviewed summary of the evidence. References are provided for these points in the article, but have not been checked for this evidence package.

[120] The modeling exercise is necessarily built on simplified assumptions, but is detailed and carried in a peer-referenced journal. Although there are important differences the climate of the North East United States is in many ways similar to that of the UK.

[121] The study showed a statistically significant correlation, even after controlling for confounding variables. Confounding variables are alternative explanatory factors such as the neighborhoods' level of wealth or deprivation. This article has not been reviewed for this evidence package beyond the abstract and this would be necessary to assess whether appropriate confounding variables were assessed for, but the study is published in a peer referenced journal. **THE STUDY IS CLEAR THAT THE CORRELATION IS NOT ENOUGH EVIDENCE TO INFER A CAUSAL RELATIONSHIP**.

[122] Notice that this is an average figure so some communities will be affected much more strongly than others.

[123] The modeling assumed that 75% of its green area was grassland, 20% Sycamore maple and 5% Douglas fir.

[124] O_3, PM_{10}, NO_2 and SO_2 and CO_2 were modeled and Hawaii and Alaska were excluded. Due to the assumptions made the figures are offered as a first order approximation. It is important to note that although the figures sound large they were typically only 1% air quality improvements during the day time during the in-leaf season. The US wide modeling shows the strongest benefits for areas with long in-leaf seasons and low rainfall - rather different circumstances to the UK! The dollar figure is arrived at by multiplying pollution removed by 'official' damage costs of this pollutant. It has not been possible to locate the reference given for these and such US wide figures can only be treated as an indicative value.

Noise

Introduction

4.87 This section reviews the evidence that Green Infrastructure can contribute to noise reduction. Noise is defined as 'unwanted sound' and evidence for health affects is complicated by the interactions by contextual factors, emotional-psychological responses and coping patterns (Stansfeld and Matheson, 2003). However a review of the evidence shows that it interferes in complex task performance, modifies social behavior and causes annoyance (Stansfeld and Matheson, 2003). Additionally exposure to air-craft and road traffic noise are associated with psychological symptoms (Stansfeld and Matheson, 2003) In children, chronic aircraft noise exposure impairs reading comprehension and long-term memory and may be associated with increased blood pressure (Stansfeld and Matheson, 2003). The World Health Organisation guidelines for Europe recommend that people should not be subjected to night-time noise levels greater than 40 decibels; in Europe almost 34 million people may be exposed to more than 50 decibels at night (European Environment Agency, 2010).

Propositions

- Green Infrastructure can contribute to noise reduction.
- Green Infrastructure alters the balance of sound towards natural sounds (particularly bird song) which considered pleasant.

Can the benefit be quantified?

4.88 In principle yes, although I am not aware of any widely accepted rules of thumb.

How strong is the evidence?

4.89 The presence of vegetation, and soft rather than hard surfaces, reduces the extent to which sound carries around urban areas (Bolund and Hunhammar, 1999). Soft lawns and dense tall vegetation reduce the extent to which sound carries, although sources differ in their quantification of this effect. Lawns reduce noise by reducing reflection of the sound wave, an effect which accounts for the quietness experienced after snowfall. Tall vegetation absorbs lateral short wave length sound (Barth and Schmid, 2001 p 79 - 104). Sounds travel further over water (Bolund and Hunhammar, 1999).

4.90 People exhibit strong preference hierarchy with regard to sound exposure, with mechanical sounds liked least, followed by human sounds and with natural sounds preferred. More natural greenspace, particularly with a significant shrub layer can encourage the production of bird song and the same time as providing habitat for threatened bird species (Irvine *et al*., 2009).

Example

- Courtyards on the quiet side of building can reduce the level of road traffic noise annoyance by providing some quieter outside space. A study in Sweden found that the quality of the courtyard in terms of 'naturalness' and features such as benches and playgrounds as well as the noise level had a significant impact in reducing noise annoyance[125] (Gidlöf-Gunnarsson and Öhrström, 2010).

---

[125] The study was based on questionnaire responses in four cities areas in Stockholm and Gothenburg. Appropriate controls were put in place with regard to sound levels on the noisy and on the quiet sides of the building, similar types of traffic, similar types of houses, and ensuring that there were no patterned differences to age or country of origin. Courtyard quality was assessed in terms of presence of outdoor furniture, playgrounds for children, presence of flowers in pots or beds and the aspect (very important that far North). At 63 - 68 decibels (the

higher level assessed) 42% of residents reported annoyance with low quality courtyards and only 29% with high quality courtyards).

4c: Provisioning services

4.91 Provisioning services differ from the other environmental services highlighted in this document in that they produce private goods which are traded in markets. Therefore they have direct economic **IMPACT**, featuring in national accounts and GDP figures. This means that they receive a great deal more policy attention than **regulating** or **health and social** services. However much of this focus is on maximizing short-term profit, which leads to three significant concerns not addressed by the market. Firstly, current production systems produce significant environmental costs, which are not included in the price paid for food by consumers or farmers, and do damage to other parts of our economy and society (Jacobs, 2008). Secondly, some of these environmental costs undermine the basis on which the provisioning services are produced, undermining the basis of production. Thirdly, production is often dependent on non-renewable resources including fossil fuels.

Food

Introduction

4.92 Food occupies an ambiguous place within our national economy. In GDP terms agriculture now represents only 0.6 percent of the economy (DEFRA *et al*., 2009), ranging from 0% in London to 2.5% in the South West[126] (ONS, 2000). This makes it marginal in economic policy terms. However this belies its importance in a number of ways. Firstly the agri-food sector accounts for 8% of GDP and 12% of employment[127] (DEFRA, 2002). More broadly farming and food have important cultural benefits which are discussed in the **Health and Society** and under **Chapter 2 theme**. Furthermore the low value of food is caused by its abundance; under any situation where food supply is insufficient for demand its value is second only to freshwater. Environmental challenges, growing population and economic growth are expected to put significant strain on the global food production system in the medium term (Foresight, 2011). Politically, this concern about food security is often used to justify maximizing production in an attempt to become self-sufficient. However, food security is the ability to keep producing over the medium to long term. The danger is that pursuing maximum yields have high intensity crops now, may undermine longer term food-security by degrading the ecosystems that agricultural production ultimately depends on[128]. This means that there are synergies between concerns about food security and concerns about biodiversity and human health. A recent government report on global agriculture suggests that that the negative consequences for the environment from food production should be internalized within the food system (Foresight, 2011). This means that government policy would ensure that these negative costs (for example cleaning of water contaminated by pollutants from agriculture), were charged to food producers, rather than society in general, altering food producer's incentives in a socially beneficial manner.

Production chain

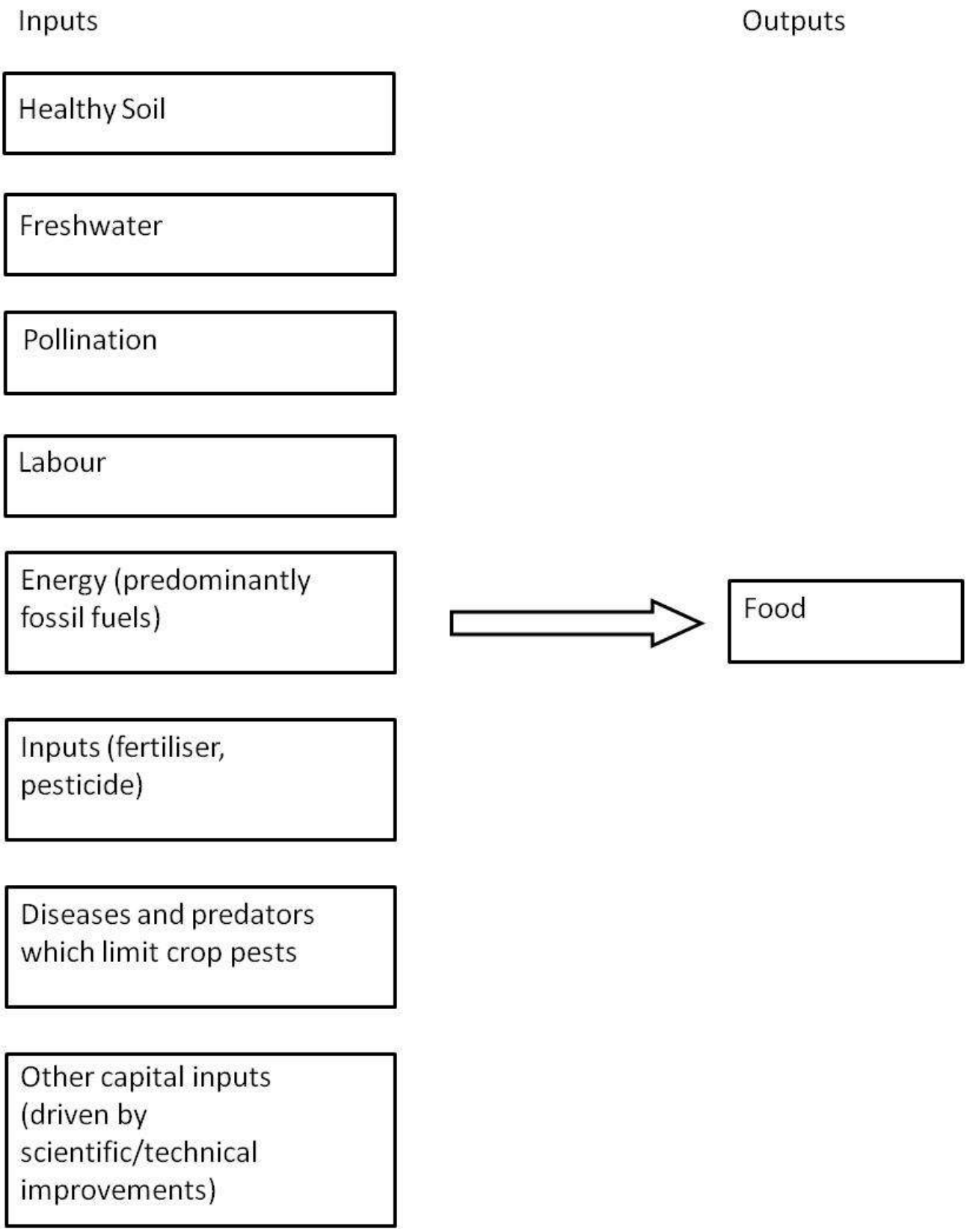

Figure 13

4.93 It is also important to note that the UK imports a significant quantity of its food and is highly integrated into world markets, so that international food availability will impact on our food supply and farming (Foresight, 2011).

Can the benefit be quantified?

4.94 Yes, although there remain significant areas of uncertainty around the natural science.

What is the relevant evidence?

Threats

- Food prices spiked dramatically round the world in 2007 - 08. Reasons included poor harvests, increased demand from middle-income countries, increased energy prices, policies to support bio-fuels, export restrictions and possibly commodity speculation (Foresight, 2011).
- Global population is expected to rise to 8 billion by 2030 and over 9 billion by 2050; this plus economic growth will increase pressure on limited resources (Foresight, 2011).
- Climate change poses multiple threats to the ecosystems on which farming relies including changes to growing seasons, droughts and floods, increased heat stress in livestock, more storm damage and increase risks of pests and diseases (DEFRA, 2009). It may also reduce organic matter in soils (Jenkinson *et al*.,1991), which would lead to loss of fertility, water holding capacity and poorer soil structure, exacerbating pollution and flooding.
- Several parts of the food system are vulnerable to higher energy costs (particularly from oil) (Foresight, 2011). There is concern that the cost of oil could rise and become more volatile in coming decades, raising the cost of synthetic fertilisers (Foresight, 2011). This effect could be exacerbated by climate change mitigation policy.
- Increased population and the use of bio-fuels is likely to increase the pressure on land use (Foresight, 2011). Additionally, land globally is likely to be lost to urbanisation, desertification, salinisation and sea-level rise (Foresight, 2011). About 24% of the vegetated land globally has already been degraded (Foresight, 2011).
- Food production relies on supplies of freshwater, which are threatened by climate change. Although agriculture uses a relatively amount of water, peak demand is when supplies are most limited. In East Anglia 20% of all abstraction is used for spray irrigation in a typical summer (Environment Agency, 2008a) (see **Freshwater**).
- Food production requires phosphorous. Phosphorous is added to soil and fertiliser after being mined as phosphate rock, but it is estimated that global supplies of phosphate rock will be depleted in 50 - 100 years with a likelihood of large spikes in prices once peak production has been passed (Cordell *et al*., 2009)[129].
- Honey bees (*Apis mellifera*) play a role in pollinating commercial crops in England. On the best available evidence the value of crops pollinated by honey bees is approximately £117 million (ADAS, 2001)[130]. Honey bees are susceptible to pests and diseases, which have increased significantly in the UK over the last 5 to 10 years (DEFRA and WAG, 2009).
- The absence of flowers throughout the landscape is a major factor limiting the number of insects available for the pollination of wild flowers and agricultural crops (Potts *et al*., 2010, Carvell *et al*., 2006)[131].
- One of the major risks of further intensification of farming, through the application of new technologies, is further decline in the quality of ecosystem services and natural capital (Foresight, 2011).

Opportunities

- It has been estimated that the UK's environmental stewardship schemes reduce emissions by between 0.44% and 0.49% of the 1990 Kyoto baseline over a 100 year time frame (DEFRA, 2007c). This benefit is largely due to the move to less intensive land management - eg less fossil fuel inputs, less deep tillage, undercrops (DEFRA, 2007c). This amounts to net savings of 1.0 million tonnes of CO_2 equivalent from Entry Level Stewardship (worth £53 million) and 4.1 million tonnes of CO_2 equivalent from Higher Level Stewardship (worth £211 million) with a combined total of 5.1 million tonnes of CO_2 equivalent (worth £264 million) (FERA, 2010)[132].

- A European wide consultation with experts found that organic farming generally operates at a lower nutrient surplus which provides the potential for higher diversity of wildlife habitats. Whilst not being a panacea, this makes organic farming the least detrimental farming system with regard to biodiversity and landscape (Stolze *et al*., 2000). Whilst it is impossible to give specific results at European scale due to contextual factors, other longitudinal site-specific studies have also found evidence of improved biodiversity[133] (Mäder *et al*., 2002).
- Organic farming tends to conserve soil and system stability better than conventional farming, due to mostly higher levels of organic matter and biological activity. This gives organic farming higher erosion control potential. (Stolze *et al*., 2000). Whilst it is impossible to give specific results at European scale due to contextual factors, other longitudinal site-specific studies have also found evidence of improved soil quality, fertility and reduced soil erosion[134] (Reganold *et al*., 1987, Mäder *et al*., 2002).
- Most research indicates that energy consumption is lower on organic farms than on conventional and that energy efficiency is better for the majority of products[135] (Stolze *et al*., 2000).
- New technologies may help us to increase production whilst reducing environmental damage[136] (Foresight, 2011). An example is precision farming, which uses GPS technology to target agrichemical applications to precise locations within fields.
- Reducing food waste and changing diets would support population health and provide nutrition more efficiently, reducing impact on the environment and therefore increasing food security. It is estimated that 30 - 50% of food is wasted worldwide[137] (Foresight, 2011).
- Crops Wild Relatives, and rare breeds, provide an essential genetic bank for producing food in novel circumstances (Foresight, 2011). Additionally plants or fungi which are not normally considered crops may have potential for food (Juárez-Montiel *et al*., 2011) or as forage.

---

[126] Agriculture is defined as agriculture, hunting, forestry and fishing. North East 0.7%, North West 0.9%, Yorkshire and Humber 1.6%, East Midlands 2.0%, West Midlands 1.5%, East 1.7%, London 0%, South East 0.8%, South West 2.5%.

[127] The agro-food sector additionally includes the food and drink and catering industries.

[128] In fact, (Foresight, 2011) suggests that it is middle to low-income countries which have the greatest capacity to sustainably increase production. Regional case study R1 (see **http://www.bis.gov.uk/foresight**) sees 2% per annum as an upper limit for productivity growth and cites the need need to maintain or improve the delivery of non-provisioning ecosystem services from land and water; the need to mitigate greenhouse gas emissions; competition for land, particularly for the generation of renewable non-food resources, but notes opportunities particularly through the re-use of on-farm waste.

[129] As an element phosphorous cannot be manufactured, but agricultural sustainability can be assured by the recycling of wastes back to the fields, including human wastes. More limited use of phosphorous would also have positive side effects in terms of reducing eutrophication.

[130] This estimate is produced by consultants to DEFRA and is based on best available scientific estimates of which crops are reliant on bee pollination and the extent to which they are reliant on it. It is important to note however, that the literature used is not peer-reviewed and there are significant methodological difficulties in achieving accurate estimates. The estimate is based on figures from the year 2000 and so strictly speaking needs adjusting for inflation and changes to agricultural production since then. This should be viewed as bare minimum estimate of the value of bees, which have a role in pollinating garden and wild plants, including many red book species (ADAS, 2001).

[131] Whilst pointing to the reduction in quantity and quality of habitat, the authors suggest that honey bee loss might be caused by multiple drivers and the relationships between habitat, pests, pesticides and genetic diversity. Many different kinds of wild pollinator species are responsible for pollination and no single species is capable of pollinating all types of plants.

[132] These figures to do not take into account displacement of food production, either within the UK, or overseas, which could radically change the outcome. They are also based on averages and do not model soil, weather and farming practice variations. The results also assume no reversion to previous practices, which is quite likely when the current schemes come to an end, suggesting we need to consider countryside management over a longer timeframe.

[133] Based on a 21 year comparative study in Central Europe.

[134] Mader *et al's* study was a 21 year comparative study in Central Europe. The Reganold study compared otherwise similar fields which had been under organic and conventional farming practices since 1948.
[135] The study is based on asking experts from across Europe for their views based on a review of national literature. Whereas it is uncontroversial that organic system use lower levels of energy per hectare, whether it is more efficient per unit output is more contested. The studies reported in this literature review found it to be more efficient for all products considered, except potatoes, for which it was found to be less efficient. However, a great deal of uncertainty remains in this area, not least because different research draws different boundaries around the energy use in its analysis.
[136] The report contains research and examples of such 'sustainable intensification' - these have not been reviewed for this evidence package. The science around the sustainability of new technology is often controversial and new downside risks may not be immediately apparent.
[137] This definition includes food fit for human consumption which is intentionally used as animal fodder.

Freshwater

Introduction

4.95 This section deals with the yield of freshwater, which is provided by the climate system through rain and then collected and delivered through technologically augmented landscape processes, such as dams and pipe works. Issues about water quality due to filtration are dealt with under **water purification and treatment**, and flow regulation in order to prevent floods is dealt with under **flood control**. Current levels of demand for water abstraction already present problems, and these are particularly acute during summer droughts (Environment Agency, 2008a). This is expected to become more acute in the coming century (Environment Agency, 2008a). This is significant because, as an essential good, demand for water only responds weakly to price changes. This means that under circumstances of water shortage consumer willingness-to-pay increases dramatically.

Production Chain

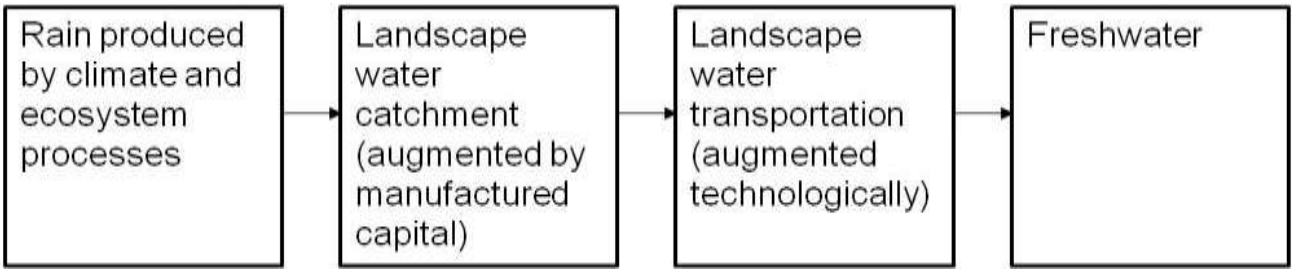

Figure 14 Production chain

Proposition

4.96 There are changes that can be made to land use and land management which will help to ensure sufficient freshwater availability.

Can the benefit be quantified?

4.97 Fundamentally yes, although there is of course considerable uncertainty about future scenarios.

How strong is the evidence?

4.98 Rain which infiltrates the ground is stored in underground aquifers. This groundwater is particularly valuable because it is normally pure and needs little treatment (Environment Agency). Groundwater directly provides one third of the water we drink and is vital source of water for rivers and wetlands, effectively storing water from wetter months and making it available in drier months (Environment Agency). Recharging aquifers through ground infiltration is therefore economically and environmentally valuable.

Rural

4.99 Intensification of farming since the Second World War has led to a number of changes to the farmed environment which reduces the rate of infiltration. These include loss of hedgerows, overgrazing, channelized rivers, and winter crops leading to bare and compacted soil (O'Connell *et al*., 2005). Grass buffers, temporary ponds, appropriate ditching and decanalisation, may therefore contribute to increased infiltration (O'Connell *et al*., 2005). There a few studies into the effects of less intensive farming, but those that exist support the view that less intensive farming leads to increased infiltration due to greater presence of the features above and healthier soil (O'Connell *et al*., 2005). Wetlands also play a role in aquifer recharge (World Resources Institute, 2008).

4.100 Woodland can help increase the infiltration rate of water into the soil (Nisbet *et al*., in press). However, trees are also significant water users, although the type of tree and context are

important. Evidence suggests that large scale planting of new conifer or energy crop woodland should be avoided in areas of low water availability (Nisbet *et al*., in press).

Urban

4.101 New urban developments can reduce ground infiltration through the building of non-porous surfaces (Environment Agency). Water efficiency systems in new build houses can mitigate this effect (Environment Agency). Sustainable Urban Drainage (SUDS) systems can increase aquifer recharge through porous paving systems allowing water to reach the soil (Carter and Butler, 2008) and through detention ponds (Environment Agency, 2007).

Connections with climate change

- For all regions an increase in winter rainfall and a decrease in summer rainfall is projected by the 2040s under virtually all climate change scenarios. It is projected that average summer rainfall in the South West will be lower by 7% by the 2020s, 13% by the 2040s, and 23% by the 2080s[138] (DEFRA, 2009).
- Climate change may reduce the recharge of aquifers and lead to the consequent lowering of groundwater levels and mean higher demand for water by households and for crop irrigation (Environment Agency, 2008a).

Examples and figures

- South-east and Eastern England can be classified as an area under stress from water abstraction, meaning that over 20% of freshwater resources are abstracted. Compared to the rest of Europe water resources are under greater stress only in drier countries such as Cyprus, Malta, Spain and Italy. South-East England has less water per person than Morocco and Egypt[139] (Environment Agency, 2008a).
- The Environment Agency predicts that there will not be enough water in the South East of England to meet demand in the future without resorting to 'new, costly and sometimes environmentally damaging infrastructure' (Environment Agency, 2007).
- There are many areas of England where there was no water available for abstraction at flow flows, and these are not limited to the South and East of the country[140] (Environment Agency, 2008a).
- Environment Agency assessment shows that over a quarter of the ground water bodies in England are at risk of failing environmental objectives due to abstraction pressures (Environment Agency).
- There are a great many important wildlife sites which may have been affected or are under threat from water abstraction. Many of these are in East Anglia where available water resources are particularly scarce[141] (Environment Agency, 2008a.

[138] This estimate is from DEFRA's climate change adaptation projections, which are based on consideration of the world's best climate models. They use a baseline of 1961 - 1990 meaning that some of this change has already occurred. This figure is based on central estimate, which is effectively business as usual with regard to global carbon emissions. It serves as an example of information available from other regions from **http://ukcp09.defra.gov.uk**.

[139] See the cited document at **http://publications.environment-agency.gov.uk/pdf/GEHO1208BPAS-e-e.pdf** for more details and maps.

[140] See the cited document at **http://publications.environment-agency.gov.uk/pdf/GEHO1208BPAS-e-e.pdf** for maps.

[141] See the cited document at **http://publications.environment-agency.gov.uk/pdf/GEHO1208BPAS-e-e.pdf** for a map.

5 References

How the report is referenced

This package is written using the Harvard referencing system. In this system references appear immediately after the relevant point in the text like this - (Harvard 2010). Alternatively if the author is mentioned in the sentence just the date may appear in brackets like this - 'we are using the Harvard (2010) referencing system'. All the references are held in the references section, below, in alphabetical order. Where there are two or more reports by the same author you can separate them by the year in which they were published, and if two are more reports are published in the same year then letters will be used to separate them (ie, Harvard 2010a, Harvard 2010b). For academic reports you will be able to find them through Google scholar, but where there is no direct link you will have to contact the library service to get hold of the article. For other documents a web link has been included in the reference where possible.

ADAS. 2001. An Economic Evaluation of DEFRA's Bee Health Programme. DEFRA. London. source [online]. URL: **http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=13647** [Accessed 23 February 2012].

ADAS. 2008. Scoping study to assess soil compaction affecting upland and lowland grassland in England and Wales. DEFRA. London. source [online]. URL: **http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=14699** [Accessed 23 February 2012].

AEAT. 2006. Air Quality and Social Deprivation in the UK, DEFRA.

ANDERSON, BG, RUTHERFURD, ID & WESTERN, AW. 2006. An analysis of the influence of riparian vegetation on the propagation of flood waves. *Environmental Modelling & Software*, 21, 1290-1296.

ANDREWS, JE, SAMWAYS, G. & SHIMMIELD, GB. 2008. Historical storage budgets of organic carbon, nutrient and contaminant elements in saltmarsh sediments: Biogeochemical context for managed realignment, Humber Estuary, UK. *Science of the Total Environment*, 405, 1-13.

ASTHMA UK. 2010. All about Asthma / Asthma basics source [online]. URL: **www.asthma.org.uk/all_about_asthma/asthma_basics/index.html** [Accessed 17th February 2012].

BARTH, F.G. & SCHMID, A. 2001. *Ecology of sensing*, Springer Verlag.

BERMAN, M.G., JONIDES, J. & KAPLAN, S. 2008. The cognitive benefits of interacting with nature. *Psychological Science*, 19, 1207.

BIRD, W. 2004. Natural Fit: Can green space and biodiversity increase levels of physical activity. *Report for the Royal Society for the Protection of Birds*.

BOARDMAN, J, EVANS, R & FORD, J. 2003. Muddy floods on the South Downs, southern England: problem and responses. *Environmental Science & Policy*, 6, 69-83.

BOLUND, P & HUNHAMMAR, S. 1999. Ecosystem services in urban areas. *Ecological Economics*, 29, 293-301.

BOWLER, D., BUYUNG-ALI, L, T, KNIGHT & PULLIN AS. 2010a. How effective is 'greening' of urban areas in reducing human exposure to ground level ozone concentrations, UV exposure and the 'urban heat island effect'? *Collaboration for Environmental Evidence*, . Bangor: Bangor University

BOWLER, D., BUYUNG-ALI, L., KNIGHT, T. & PULLIN, A.S. 2010b. The importance of nature for health: is there a specific benefit of contact with green space? *Collaboration for Environmental Evidence* Bangor Bangor University

BOXALL, A., HARDY, A., BEULKE, S., BOUCARD, T., BURGIN, L., FALLOON, P., HAYGARTH, P., HUTCHINSON, T., KOVATS, S. & LEONARDI, G. 2010. Impacts of climate change on indirect human exposure to pathogens and chemicals from agriculture. *Ciência & Saúde Coletiva*, 15, 743-756.

BRADLEY, RI, MILNE, R., BELL, J., LILLY, A., JORDAN, C. & HIGGINS, A. 2005. A soil carbon and land use database for the United Kingdom. *Soil Use and Management*, 21, 363-369.

BRINGSLIMARK, T, HARTIG, T & PATIL, GG. 2009. The psychological benefits of indoor plants: A critical review of the experimental literature. *Journal of environmental psychology*, 29, 422-433.

BROADMEADOW, M & MATHEWS, R. 2003. Forests, Carbon and Climate Change: the UK Contribution. FORESTRY COMMISSION. Edinburgh. source [online]. URL: **www.forestry.gov.uk/pdf/fcin048.pdf/$FILE/fcin048.pdf** [Accessed 23 February 2012].

CABE SPACE. 2005. Does money grow on trees? London. source [online]. URL: **http://webarchive.nationalarchives.gov.uk/20110118095356/http:/www.cabe.org.uk/files/does-money-grow-on-trees.pdf** [Accessed 29 February 2012].

CABE SPACE. 2010. Urban green nation; Building the evidence base.

CARTER, T & BUTLER, C. 2008. Ecological impacts of replacing traditional roofs with green roofs in two urban areas. *Cities and the Environment*, 1, 9-17.

CARVELL, C., ROY, D.B., SMART, S.M., PYWELL, R.F., PRESTON, C.D. & GOULSON, D. 2006. Declines in forage availability for bumblebees at a national scale. *Biological conservation*, 132, 481-489.

CAULA, S., HVENEGAARD, GT & MARTY, P. 2009. The influence of bird information, attitudes, and demographics on public preferences toward urban green spaces: The case of Montpellier, France. *Urban forestry & urban greening*, 8, 117-128.

CHANG, CR, LI, MH & CHANG, SD. 2007. A preliminary study on the local cool-island intensity of Taipei city parks. *Landscape and Urban Planning*, 80, 386-395.

CHIEF MEDICAL OFFICER. 2004. At least five a week: Evidence on the impact of physical activity and its relationship to health. DEPARTMENT OF HEALTH.

CHRISTIE, M & MATHEWS, J. 2003. The economic and social value of walking in England. RAMBLERS.

CLES POLICY ADVICE. 2007. The Contribution of the Local Environment to the Local Economy presented to Groundwork UK.

COHEN, DA, MCKENZIE, TL, SEHGAL, A, WILLIAMSON, S, GOLINELLI, D & LURIE, N. 2007. Contribution of public parks to physical activity. *American Journal of Public Health*, 97, 509.

COLLINS, T, EMPSON, B, LEAFE, R & LOWE, J. Year. Sustainable flood defence and habitat conservation in estuaries - a strategic framework. In: 32nd MAFF Conference of river and coastal engineers, 1997.

COOMBES, EMMA, JONES, ANDREW P. & HILLSDON, MELVYN. 2010. The relationship of physical activity and overweight to objectively measured green space accessibility and use. *Social Science & Medicine*, 70, 816-822.

CORDELL, D., DRANGERT, J.O. & WHITE, S. 2009. The story of phosphorus: Global food security and food for thought. *Global Environmental Change*, 19, 292-305.

CROMPTON, JL. 2005. The impact of parks on property values: empirical evidence from the past two decades in the United States. *Managing Leisure*, 10, 203-218.

CSI. 2008. Creating a Setting for Investment: Project Report.

D'AMATO, G. & CECCHI, L. 2008. Effects of climate change on environmental factors in respiratory allergic diseases. *Clinical & Experimental Allergy*, 38, 1264-1274.

DE VRIES, S, AVERHEIJ, R, PGROENEWEGEN, P & SPREEUWENBERG, P. 2003. Natural environments-healthy environments? An exploratory analysis of the relationship between greenspace and health. *Environment and Planning A*, 35, 1717-1731.

DEFRA. 2002. Strategy for Sustainable Farming and Food: Facing the Future London.

DEFRA. 2007a. The air quality strategy for England, Scotland, Wales and Northern Ireland. DEFRA. London.

DEFRA. 2007b. An introductory guide to valuing ecosystem services. DEFRA. London.

DEFRA. 2007c. Research into the current and potential climate change mitigation impact of environmental stewardship. DEFRA. London

DEFRA. 2007d. A strategy for England's trees, woods and forests. . DEFRA. London.

DEFRA. 2009. Adapting to Climate Change: UK Climate Projections. DEFRA. London.

DEFRA, DARD (NORTHERN IRELAND), SCOTTISH GOVERNMENT, RERAD & WELSH ASSEMBLY GOVERNMENT, DRAH 2009. Agriculture in the United Kingdom. source [online]. URL: **www.defra.gov.uk/statistics/foodfarm/cross-cutting/auk/** [Accessed 23 February 2012].

DEFRA & WAG 2009. Healthy Bees. DEFRA & WAG. YORK/CARMARTHEN. source [online]. URL: **https://secure.fera.defra.gov.uk/beebase/index.cfm?sectionid=41** [Accessed 23 February 2012].

DELOITTE & OXFORD ECONOMICS. 2010. The Economic Contribution of the Visitor Economy: UK and the Nations. VISIT BRITAIN. source [online]. URL: **www.visitbritain.org/Images/Economic%20case%20for%20the%20Visitor%20Economy%20-%20Phase%202%20-%2026%20July%202010%20-%20FINAL_tcm139-192073.pdf** [Accessed 23 February 2012].

DICKIE, IAN, HUGHES, JULIAN & ESTEBAN, ANIOL. 2006. Watched Like Never Before... the local economic benefits of spectacular bird species. RSPB.

DOWNING, JA, COLE, JJ, MIDDELBURG, JJ, STRIEGL, RG, DUARTE, CM, KORTELAINEN, P., PRAIRIE, YT & LAUBE, KA. 2008. Sediment organic carbon burial in agriculturally eutrophic impoundments over the last century. *Global Biogeochemical Cycles*, 22, GB1018.

DUFFY, A, JEFFERIES, C, WADDELL, G, SHANKS, G, BLACKWOOD, D & WATKINS, A. 2008. A cost comparison of traditional drainage and SUDS in Scotland. *Water Science & Technology*, 57, 1451-1459.

EBI, K & MCGREGOR, G. 2009. Climate change, tropospheric ozone and particulate matter, and health impacts. *Ciência & Saúde Coletiva*, 14, 2281-2293.

EFTEC. 2009. Economic valuation of uplands ecosystem services. report to Natural England

ENVIRONMENT AGENCY. The Land Use Jigsaw. Bristol

ENVIRONMENT AGENCY. Underground, under threat. Bristol source [online]. URL: **www.environment-agency.gov.uk/research/library/publications/40741.aspx** [Accessed 23 February 2012].

ENVIRONMENT AGENCY. 2007. Response to Royal Commission on Environmental Pollution consultation 'Urban Environment'. source [online]. URL: **www.rcep.org.uk/reports/26-urban/documents/urb-env-summary.pdf** [Accessed 23 February 2012].

ENVIRONMENT AGENCY. 2008a. Water resources in England and Wales - current state and future pressures. ENVIRONMENT AGENCY. source [online]. URL: **http://publications.environment-agency.gov.uk/pdf/GEHO1208BPAS-e-e.pdf** [Accessed 23 February 2012].

ENVIRONMENT AGENCY. 2008b. Working towards a better quality of life: Environmental justice in South Yorkshire: summary report.

EUROPEAN ENVIRONMENT AGENCY. 2010. The European environment — state and outlook 2010: synthesis. Copenhagen.

EVERAD, M. 2009. Ecosystem Services Case Studies - Science Report. ENVIRONMENT AGENCY. Bristol.

FERA. 2010. Estimating the wildlife and landscape benefits of environmental stewardship. York: Food and Environment Research Agency

FORESIGHT. 2004. Future Flooding DIUS. London.

FORESIGHT. 2007. Tackling Obesities: Future Choices DIUS. London.

FORESIGHT. 2011. The Future of Food and Farming: Challenges and choices for global sustainability GOVERNMENT OFFICE FOR SCIENCE. London

FORESTRY COMMISSION. Bold Colliery Community Woodland; District Valuer's report on Property Values.

FULLER, R.A., IRVINE, K.N., DEVINE-WRIGHT, P., WARREN, P.H. & GASTON, K.J. 2007. Psychological benefits of greenspace increase with biodiversity. *Biology Letters*, 3, 390.

GAMBRELL, RP. 1994. Trace and Toxic Metals in Wetlands A Review. *Journal of Environmental Quality*, 23, 883.

GARROD, G. 2002. Landscape benefits Social & Environment Benefits of Forestry Phase 2: . Edinburgh Report to the Forestry Commission

GARROD, GD & WILLIS, KG. 1992. Valuing goods' characteristics: an application of the hedonic price method to environmental attributes. *Journal of environmental management*, 34, 59-76.

GEN CONSULTING. 2006. Glasgow Green Renewal Benefits Analysis. A report to Glasgow City Council

GENSLER, INSTITUTE, URBAN LAND & NETWORK, URBAN INVESTMENT. 2011. Open Space: an asset without a champion?

GIDLÖF-GUNNARSSON, A. & ÖHRSTRÖM, E. 2010. Attractive" Quiet" Courtyards: A Potential Modifier of Urban Residents' Responses to Road Traffic Noise? *International Journal of Environmental Research and Public Health*, 7.

GILES-CORTI, B, BROOMHALL, MH, KNUIMAN, M, COLLINS, C, DOUGLAS, K, NG, K, LANGE, A & DONOVAN, RJ. 2005. Increasing walking:: How important is distance to, attractiveness, and size of public open space? *American journal of preventive medicine*, 28, 169-176.

GILL, SE, HANDLEY, JF, ENNOS, AR & PAULEIT, S. 2007. Adapting cities for climate change: the role of the green infrastructure. *Built Environment*, 33, 115-133.

GILLIAM, JW. 1994. Riparian wetlands and water quality. *Journal of Environmental Quality*, 23, 896.

GLA ECONOMICS. 2003. Valuing greeness: Green spaces, house prices, and Londoners priorities

GOBSTER, PH. 1998. Urban parks as green walls or green magnets? Interracial relations in neighborhood boundary parks. *Landscape and Urban Planning*, 41, 43-55.

GRAHN, P & STIGSDOTTER, UA. 2003. Landscape planning and stress. *Urban forestry & urban greening*, 2, 1-18.

GREATER LONDON AUTHORITY. 2006. London's Urban Heat Island a summary for decision-makers. source [online]. URL: **http://static.london.gov.uk/mayor/environment/climate-change/docs/UHI_summary_report.pdf** [Accessed 29 February 2012].

GREENSPACE. 2007. The Park Life report,.

GUITE, HF, CLARK, C & ACKRILL, G. 2006. The impact of the physical and urban environment on mental well-being. *Public health*, 120, 1117-1126.

HATT, BE, FLETCHER, TD & DELETIC, A. 2008. Hydraulic and Pollutant Removal Performance of Fine Media Stormwater Filtration Systems. *Environ. Sci. Technol*, 42, 2535-2541.

HEAL, KV, HEPBURN, DA, LUNN, RJ & TYSON, J. 2006. Sediment management in sustainable urban drainage system ponds. *Water Science and Technology*, 53, 219-228.

HEALTH COUNCIL OF THE NETHERLANDS. 2004. Nature and Health. NATURE AND FOOD QUALITY AGRICULTURE. The Hague

HEALTH IMPROVEMENT ANALYTICAL TEAM & UNIT, MONITORING 2010. Health profile of England. 2009. DEPARTMENT OF HEALTH.

HILL, G, COURTNEY, P, BURTON, R & J, POTTS. 2003. Forests' role in Tourism: Phase 2. *Summary report - Final* for the Forestry Group (Economics & Statistics) of the Forestry Commission.

HILLSDON, M, PANTER, J, FOSTER, C & JONES, A. 2006. The relationship between access and quality of urban green space with population physical activity. *Public health*, 120, 1127-1132.

HILLSDON, M & THOROGOOD, M. 1996. A systematic review of physical activity promotion strategies. *British Medical Journal*, 30, 84.

HIRSCHFIELD, A & BOWERS, KJ. 1997. The Effect of Social Cohesion on Levels of Recorded Crime in Disadvantaged Areas. *Urban Studies*, 34, 1275-1295.

HM TREASURY. 2003. The Green Book: Appraisal and Evaluation in Central Government. London.

HOLMAN, IP, HOLLIS, JM, BRAMLEY, ME & THOMPSON, TRE. 2003. The contribution of soil structural degradation to catchment flooding: a preliminary investigation of the 2000 floods in England and Wales. *Hydrology and Earth System Sciences*, 7, 755-766.

HOME OFFICE. 2003/04. The economic and social costs of crime against individuals and households.

IRVINE, KATHERINE N., DEVINE-WRIGHT, PATRICK, PAYNE, SARAH R., FULLER, RICHARD A., PAINTER, BIRGIT & GASTON, KEVIN J. 2009. Green space, soundscape and urban sustainability: an interdisciplinary, empirical study. *Local Environment: The International Journal of Justice and Sustainability*, 14, 155 - 172.

JACKSON, BM, WHEATER, HS, MCINTYRE, NR, CHELL, J, FRANCIS, OJ, FROGBROOK, Z, MARSHALL, M, REYNOLDS, B & SOLLOWAY, I. 2008. The impact of upland land management on flooding: insights from a multiscale experimental and modelling programme. *Journal of Flood Risk Management*, 1, 71-80.

JACOBS. 2008. Environmental Accounts for Agriculture: Final Report. DEFRA, WAG, SCOTTISH GOVERNMENT & DARD (NI).

JEFFRIES, R, DARBY, SE & SEAR, DA. 2003. The influence of vegetation and organic debris on flood-plain sediment dynamics: case study of a low-order stream in the New Forest, England. *Geomorphology*, 51, 61-80.

JENKINSON, DS, ADAMS, DE & WILD, A. 1991. Model estimates of CO_2 emissions from soil in response to global warming. *Nature*, 351, 304-306.

JONES, AP, COOMBES, E & HILLSDON, M 2010. The relationship of physical activity and overweight to objectively measured green space accessibility and use. *Social Science & Medicine*.

JUÁREZ-MONTIEL, M., LEÓN, S.R., CHÁVEZ-CAMARILLO, G., HERNÁNDEZ-RODRÍGUEZ, C. & VILLA-TANACA, L. 2011. El Huitlacoche (tizón del maíz), causado por el hongo fitopatógeno Ustilago maydis, como alimento funcional. *Revista Iberoamericana de Micología*.

KAPLAN, R & KAPLAN, S. 1989. *The experience of nature: A psychological perspective*, Cambridge Univ Pr.

KAWACHI, I, KENNEDY, BP, LOCHNER, K & PROTHROW-STITH, D. 1997. Social capital, income inequality, and mortality. *American Journal of Public Health*, 87, 1491.

KOVATS, S (ED). 2008. Health effects of climate change in the UK 2008: : An update of the Department of Health report 2001/2002. HEALTH PROTECTION AGENCY.

KRZYANOWSKI, M, KUNA-DIBBERT, B & SCHNEIDER, J. 2005*. Health effects of transport-related air pollution*, World Health Organization.

KUMAR, R & KAUSHIK, SC. 2005. Performance evaluation of green roof and shading for thermal protection of buildings. *Building and Environment*, 40, 1505-1511.

KUO, FE & SULLIVAN, WC. 2001. Environment and crime in the inner city: Does vegetation reduce crime? *Environment and Behavior*, 33, 343.

LAYARD, R. 2006. The depression report: a new deal for depression and anxiety disorders. London School of Economics - Political Science - Centre for Economic Performance.

LOVASI, GS, QUINN, JW, NECKERMAN, KM, PERZANOWSKI, MS & RUNDLE, A. 2008. Children living in areas with more street trees have lower prevalence of asthma. *Journal of epidemiology and community health*, 62, 647.

LOWRANCE, R, ALTIER, LS, NEWBOLD, JD, SCHNABEL, RR, GROFFMAN, PM, DENVER, JM, CORRELL, DL, GILLIAM, JW, ROBINSON, JL & BRINSFIELD, RB. 1997. Water quality functions of riparian forest buffers in Chesapeake Bay watersheds. *Environmental Management*, 21, 687-712.

LUISETTI, T., TURNER, K. & BATEMAN, I. 2008. An ecosystem services approach to assess managed realignment coastal policy in England. CSERGE Working Paper, 08-04.

LUTTIK, J. 2000. The value of trees, water and open space as reflected by house prices in the Netherlands. *Landscape and Urban Planning*, 48, 161-167.

MAAS, J, VERHEIJ, RA, GROENEWEGEN, PP, DE VRIES, S & SPREEUWENBERG, P. 2006. Green space, urbanity, and health: how strong is the relation? *Journal of epidemiology and community health*, 60, 587.

MÄDER, P., FLIESSBACH, A., DUBOIS, D., GUNST, L., FRIED, P. & NIGGLI, U. 2002. Soil fertility and biodiversity in organic farming. *Science*, 296, 1694.

MADGE, C. 1997. Public parks and the geography of fear. *Tijdschrift voor economische en sociale geografie,* 88, 237-250.

MCMANUS, S & BEBBINGTON, P. 2009. *Adult psychiatric morbidity in England, 2007: results of a household survey*, National Centre for Social Research.

MENTENS, J, RAES, D & HERMY, M. 2006. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? *Landscape and Urban Planning*, 77, 217-226.

MEYERHOFF, J & DEHNHARDT, A. 2007. The European Water Framework Directive and economic valuation of wetlands: the restoration of floodplains along the River Elbe. *European Environment*, 17, 18-36.

MIND. 2007. Ecotherapy: The Green Agenda for Mental Health. source [online]. URL: **www.mind.org.uk/campaigns_and_issues/report_and_resources/835_ecotherapy** [Accessed 23 February 2012].

MITCHELL, R & POPHAM, F. 2008. Effect of exposure to natural environment on health inequalities: an observational population study. *The Lancet*, 372, 1655-1660.

NAO. 2006. Enhancing Urban Green Space. ODPM. London.

NAPIER, F, JEFFERIES, C, HEAL, KV, FOGG, P, ARCY, BJ & CLARKE, R. 2009. Evidence of traffic-related pollutant control in soil-based Sustainable Urban Drainage Systems (SUDS). *Water science and technology: a journal of the International Association on Water Pollution Research*, 60, 221.

NATIONAL TRUST. 1999. 'Valuing our Environment: a study of the economic impact of conserved landscapes and of the National Trust in the South-West 1998'.

NATURAL ENGLAND. 2009a. An estimate of the value and cost effectiveness of the expanded Walking the Way to Health Initiative scheme 2009. source [online]. URL: **http://publications.naturalengland.org.uk/publication/35009** [Accessed 29 February 2012].

NATURAL ENGLAND. 2009c. No charge? Valuing the natural environment.

NATURAL ENGLAND. 2010. England's peatlands; carbon storage and greenhouse gases. source [online]. URL: **http://publications.naturalengland.org.uk/publication/30021** [Accessed 29 February 2012].

NEIL DUNSE, DEHRING, CAROLYN & WHITE, MICHAEL. 2007. Urban parks, open space and residential property values.

NEUVONEN, M, SIEVÄNEN, T, TÖNNES, S & KOSKELA, T. 2007. Access to green areas and the frequency of visits-A case study in Helsinki. *Urban forestry & urban greening*, 6, 235-247.

NIELSEN, TS & HANSEN, KB. 2007. Do green areas affect health? Results from a Danish survey on the use of green areas and health indicators. *Health & Place*, 13, 839-850.

NISBET, T.R., SILGRAM, M., SHAH, N., MORROW, K. & BROADMEADOW, S. in press Woodland for water: a review of woodland measures for River Basin and Catchment Flood Management Plans. EA/FC. Bristol.

NOWAK, DJ, CIVEROLO, KL & TRIVIKRAMA RAO, S. 2000. A modeling study of the impact of urban trees on ozone. *Atmospheric Environment*, 34, 1601-1613.

NOWAK, DJ, CRANE, DE & STEVENS, JC. 2006. Air pollution removal by urban trees and shrubs in the United States. *Urban forestry & urban greening*, 4, 115-123.

NYC ENVIRONMENTAL PROTECTION. 2010. NYC Green Infrastructure Plan: A sustainable strategy for clean waterways.

O'CONNELL, P. E., BEVEN, K. J., CARNEY, J. N., CLEMENTS, R. O., EWEN, J., FOWLER, H., HARRIS G. L, HOLLIS, J., MORRIS, J., O'DONELL, G. M., PACKMAN, J. C, PARKIN, A., QUINN, P. F., ROSE, S. C., SHEPHERD, M. & TELLIER S. 2005. Review of impacts of rural land use and management on flood generation Impact study report. DEFRA.

ONS. 2000. Regional Trends 37.

PARK, J. & CLUCKIE, I. 2006. Whole catchment modelling project. TECHNICAL REPORT TO THE ENVIRONMENT AGENCY.

PARKINSON, M, HUTCHINS, M, SIMMIE, J, CLARK, G & VERDONK, H. 2004. Competitive European Cities: Where do the core cities stand. *Office of the Deputy Prime Minister, London*.

PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY. 2007. Urban flooding.

PIKORA, T, GILES-CORTI, B, BULL, F, JAMROZIK, K & DONOVAN, R. 2003. Developing a framework for assessment of the environmental determinants of walking and cycling. *Social Science & Medicine*, 56, 1693-1703.

PITT, M. 2008. Learning lessons from the 2007 floods. CABINET OFFICE.

POST. 2004. UK health impacts of climate change. PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY.

POSTEL, SL & THOMPSON JR, BH. Year. Watershed protection: Capturing the benefits of nature's water supply services. *In*, 2005. Wiley Online Library, 98-108.

POTTS, S.G., BIESMEIJER, J.C., KREMEN, C., NEUMANN, P., SCHWEIGER, O. & KUNIN, W.E. 2010. Global pollinator declines: trends, impacts and drivers. *Trends in Ecology & Evolution*, 25, 345-353.

PRUPIM DEVELOPMENTS. Green Park Reading, source [online]. URL: **www.prupim.com/site/.../2775_GreenPark_case_study_24_sept.pdf** [Accessed 17 February 2012].

RAYMENT, M & DICKIE, I. 2001. Conservation Works...for local economies in the UK Sandy RSPB.

RAYMENT, M, LEWIS, P, HENDERSON, R & BROOM, G. 2000. Valuing Norfolk's Coast. *The Economic Benefits of Environmental and Wildlife Tourism* Sandy: RSPB.

REACHER, M, MCKENZIE, K, LANE, C, NICHOLS, T, KEDGE, I, IVERSEN, A, HEPPLE, P, WALTER, T, LAXTON, C & SIMPSON, J. 2004. Health impacts of flooding in Lewes: a comparison of reported gastrointestinal and other illness and mental health in flooded and non-flooded households. *Communicable Disease and Public Health*, 7, 39-46.

READ, D.J., FREER-SMITH, P.H., MORISON, J.I.L., HANLEY, N., WEST, C.C. & SNOWDON, P. (EDS). 2009. Combating climate change - a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change. Edinburgh.

REBANKS CONSULTING LIMITED. 2010. The Economic Benefits of Ecosystem Services in the Bassenthwaite Catchment

REGANOLD, J.P., ELLIOTT, L.F. & UNGER, Y.L. 1987. Long-term effects of organic and conventional farming on soil erosion.

RICHARDSON, CR, FAULKNER, G, MCDEVITT, J, SKRINAR, GS, HUTCHINSON, DS & PIETTE, JD. 2005. Integrating physical activity into mental health services for persons with serious mental illness. *Psychiatric services*, 56, 324.

ROBERTS, L & HALL, D. 2004. Consuming the countryside: Marketing for 'rural tourism'. *Journal of Vacation Marketing*, 10, 253.

SCHULZE, WD, MCCLELLAND, GH, LAZO, JK & ROWE, RD. 1998. Embedding and calibration in measuring non-use values. *Resources and Energy Economics*, 20, 163-178.

SHEPHERD, D., BURGESS, D., JICKELLS, T., ANDREWS, J., CAVE, R., TURNER, RK, ALDRIDGE, J., PARKER, ER & YOUNG, E. 2007. Modelling the effects and economics of managed realignment on the cycling and storage of nutrients, carbon and sediments in the Blackwater estuary UK. *Estuarine, Coastal and Shelf Science*, 73, 355-367.

SHIEL, RAYMONT & BURTON. 2002. RSPB reserves and local economies RSPB. Sandy.

STANSFELD, S.A. & MATHESON, M.P. 2003. Noise pollution: non-auditory effects on health. *British Medical Bulletin*, 68, 243.

STOLZE, M., PIORR, A., HÄRING, AM & DABBERT, S. 2000. Environmental impacts of organic farming in Europe.

SUSTAINABLE DEVELOPMENT COMMISSION. 2008. Health, place and nature - How outdoor environments influence health and well-being: a knowledge base. source [online]. URL: **www.sd-commission.org.uk/publications/downloads/Outdoor_environments_and_health.pdf** [Accessed 23 February 2012].

TAKANO, T, NAKAMURA, K & WATANABE, M. 2002. Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *Journal of epidemiology and community health*, 56, 913.

TAYLOR, AF, KUO, FE & SULLIVAN, WC. 2001. Coping with ADD: The surprising connection to green play settings. *Environment and Behavior*, 33, 54.

THE COUNTRYSIDE AGENCY. 1998. The economic impact of recreation and tourism in the English Countryside 1998. Wetherby.

THE SAINSBURY CENTRE FOR MENTAL HEALTH. 2003. The economic and social costs of mental illness.

THOMAS, H & NISBET, TR. 2007. An assessment of the impact of floodplain woodland on flood flows. *Water and Environment Journal*, 21, 114-126.

THOMPSON, D. 2008. Carbon Management by Land and Marine Managers. NATURAL ENGLAND.

TIWARY, A, SINNETT, D, PEACHEY, C, CHALABI, Z, VARDOULAKIS, S, FLETCHER, T, LEONARDI, G, GRUNDY, C, AZAPAGIC, A & HUTCHINGS, TR. 2009. An integrated tool to assess the role of new planting in PM_{10} capture and the human health benefits: A case study in London. *Environmental Pollution*, 157, 2645-2653.

TSUJI, I, TAKAHASHI, K, NISHINO, Y, OHKUBO, T, KURIYAMA, S, WATANABE, Y, ANZAI, Y, TSUBONO, Y & HISAMICHI, S. 2003. Impact of walking upon medical care expenditure in Japan: the Ohsaki Cohort Study. *International journal of epidemiology*, 32, 809.

TUNSTALL, S, TAPSELL, S, GREEN, C, FLOYD, P & GEORGE, C. 2006. The health effects of flooding: social research results from England and Wales. *Journal of water and health*, 4, 365-318.

TURNER, RK, BURGESS, D., HADLEY, D., COOMBES, E. & JACKSON, N. COASTAL MANAGEMENT IN THE 21ST CENTURY: COPING STRATEGIES FOR VULNERABILITY REDUCTION.

ULRICH, RS. 1984. View through a window may influence recovery from surgery. *Science*, 224, 420.

ULRICH, RS, SIMONS, RF, LOSITO, BD, FIORITO, E, MILES, MA & ZELSON, M. 1991. Stress recovery during exposure to natural and urban environments1. *Journal of environmental psychology*, 11, 201-230.

URBAN GREEN SPACES TASK FORCE. 2002. Green Spaces. Better Places. LOCAL GOVERNMENT AND THE REGIONS/ DEPARTMENT FOR TRANSPORT. London.

USEPA. 2010. *Heat Island effect: basic information* source [online]. URL: **www.epa.gov/hiri/about/index.htm** [Accessed 17th February 2012].

VELLIDIS, G, LOWRANCE, R, GAY, P & WAUCHOPE, RD. 2002. Herbicide transport in a restored riparian forest buffer system. *Transactions of the ASAE*, 45, 89-97.

WEBBER, M. & CHRISTIE, M.G. 2006. The Social and Economic Value of the UK's Geodiversity. *English Nature Research Reports*, 709, 1-122.

WELDON, S. , BAILEY, C. & O'BRIEN, L. 2007. New pathways to health and well-being: summary of research to understand and overcome barriers to accessing woodland. FORESTRY COMMISSION. Scotland.

WELLS, NM. 2000. At home with nature: effects of "greenness" on children's cognitive functioning. *Environment and Behavior*, 32, 775.

WILLIS, KG & GARROD, GD. 1991. An individual travel-cost method of evaluating forest recreation. *Journal of Agricultural Economics*, 42, 33-42.

WORLD RESOURCES INSTITUTE. 2008. Ecosystems and Human Well-being: Wetlands and Water [Online]. Encyclopedia of Earth website. Available: URL: **www.eoearth.org/article/Ecosystems_and_Human_Well-being:_Wetlands_and_Water:_Wetlands_and_Water:_Ecosystems_and_Human_Well-being#Wetland_Services** [Accessed 17th February 2012].

XIAO, Q, MCPHERSON, EG, SIMPSON, JR & USTIN, SL. 1998. Rainfall interception by Sacramento's urban forest. *Journal of Arboriculture*, 24, 235-244.

Appendix 1 Glossary

Glossary

Benefits transfer

The process of inferring the size of an economic benefit at the site under consideration from previous research at another site, paying careful attention to contextual changes. Sometimes called value transfer to include costs as well as benefits.

Choice experiment

Research using the choice experiment method presents participants with two or more scenarios to choose from. In these scenarios both the price (normally hypothetical taxes) and the environmental good in question vary. This allows the calculation of an implicit price for the environmental good.

Climate change adaptation

This is the process of adapting to current and expected impacts of climate change.

Climate change mitigation

This is the process of limiting the negative impacts of climate change through reducing emissions of green house gases.

Confounding

Research often seeks to ascertain the relationships between two variables, but this process can lead to misleading results if there is an intervening 'confuser variable' known as the confounder or confounding variable. For example, it is possible to show that IQ results are closely related to shoe size if you fail to consider age - children have smaller feet and score lower in IQ tests.

Controls, controlled

When there is a potential confounding variable (see above) research attempts to ascertain the actual relationship between two variables by 'controlling' for the confounding variable. In the example given above shoe size would only be compared with IQ results within the same age band, thus controlling for this confounder.

Contingent valuation method

Research using the contingent valuation method to set up a hypothetical market in order to assess how much people are willing to pay to for a good which is not traded in a market - for example how much would you be willing to pay for a 2 kilometre square high-quality bird habitat within 10 miles of your home?

Cost: benefit analysis

Cost: benefit analysis is a formalized method of considering the costs and benefits of a proposed project using values expressed in the market place and in research into the values people hold for 'non-market goods' (ie landscape or wildlife). In the UK the appropriate process is codified in the Treasury's Green Book. See introduction to economic evidence for further explanation.

Discounting (discount rate)

Discounting is an approach which allows future costs and benefits to be compared to current costs and benefits in a consistent manner, by reducing (discounting) the size of future costs and benefits by a percentage per year. See introduction to economic evidence for further explanation.

Ecosystem services

The Ecosystem Services approach provides a structured way to consider the many benefits that people receive from the natural environment and how these change under different management options.

f.t.e.

Full time equivalent. This is a method of expressing a number of jobs created, recognizing that some jobs are part-time.

Green Infrastructure

Green Infrastructure primarily refers to an approach to spatial planning which actively considers the desirably available level of ecosystem services. The term is primarily used around urban or suburban settlements, but can be used to include the whole landscape.

Hedonic price method

Hedonic research seeks to ascertain the value that people place on environmental goods through revealed market behavior which is thought to be related. The housing market and travel cost are common approaches.

Impact (economic)

Economic impact is the extent to which a proposed intervention increases the size of the traded economy, commonly measured using GDP or GVA. Careful consideration of whether the new economy activity is new or displaced is important. See introduction to economic evidence for further explanation.

Value (economic)

Economic value refers to the full impact of a change on economic welfare, regardless of whether this impact is felt through the market. So an increase in traffic noise audible in your living room constitutes a loss of economic value, even if this doesn't affect the resale value of your house. Economic value is normally assessed through asking people to value the change in a hypothetical market.

Value transfer

The process of inferring the size of an economic benefit or cost at the site under consideration from previous research at another site, paying careful attention to contextual changes. Sometimes called benefits transfer when only benefits are under consideration.

Willingness-to-pay

In order to value goods which are not traded in markets (biodiversity habitats, for example) economists may ask them how much they would be willing to pay for them in a hypothetical market. This result is a willingness-to-pay value. Note that this figure is hypothetical in that people are not actually required to pay.

Appendix 2 Methodology

Literature reviewed

Literature which is relevant to the evidence base for the economic benefits of the natural environment was reviewed for this evidence package. Much of this was economic literature, but natural and social science literature is also included.

Methodology - economic literature

Literature was preferred which was academically peer-referenced. All economic research articles were fully reviewed, but some official figures were accepted on the basis of this authority. The footnotes next to the reference provide transparency as to the extent of review. Literature was accepted or rejected based on whether it met Treasury Green Book standards (HM Treasury, 2003) for economic evidence.

Methodology - natural and social science literature

For natural and social science literature selection was based on the research quality hierarchy, where peer reviewed academic journals are given the greatest weight, followed by government research and then evidence from third-party or campaigning groups. The abstracts have at least been checked to ensure they are being referenced correctly, and many articles have been reviewed in much greater depth. I have highlighted what particular pieces of research have controlled for, to help you assess the strength of the evidence[1]. Again the footnotes provide transparency as to the depth of review. This evidence package has also been peer-reviewed by the following Natural England staff:

- Alexander, Ian
- Brotherton, Pete
- Burn, Alistair
- Cathcart, Rob
- Collins, Tim
- Clarke, Stewart
- Davies, Fran
- Harlow, Julian
- Hopkins John
- Macgregor, Nicholas
- Morecroft, Mike
- Schüder, Ingo
- Shepherd, David
- Stone, Dave
- Ward, Helen
- Waters, Ruth
- Wetherell, Anna

[1] Sometimes in research the relationship we are looking for between two variables is obscured by a third relationship we call the confounding variable. For example, it is possible to draw a graph which relates shoe size to IQ provided children are included! We can avoid this confusion though by 'controlling' for age which means that we only compare shoe size and IQ for people of the same age. Once this is done the apparent relationship disappears.

Selecting evidence

Selection of evidence to make the case requires judgment, and cannot easily be reduced to an automatic hierarchy. For example a peer-reviewed article from Canada may be less powerful than a government document from the UK, if the issue under concern is expected to vary contextually. Where international evidence refers to human characteristics which are thought to be shared globally[2], I have included them as a core part of the evidence. Also where international evidence refers to biological properties of the natural environment this also been incorporated. However, where the research refers to societal and social factors, which can be expected to vary significantly from place to place, they are not included as a core part of the evidence for the logic chain, but may be referred to as interesting. With regard to examples and figures I have preferred English based case studies, but where this is not possible have used international ones with a preference for developed world case studies.

I have included research on the basis that it is of good quality and helpful in making the case. There is therefore a great deal of literature which was reviewed for this evidence package which is not referred to in this document. Clearly, with such a large subject, time limitations have also meant that I have not been able to review all the relevant literature. If you have recommendations for evidence to include in a draft 2.0 please e-mail me at **tim.sunderland@naturalengland.org.uk**. However, be warned, for some of the economic articles I have deconstructed them and used the evidence which I consider to be defensible and useful. Therefore quoting from a study does not mean that I consider all of the study to be defensible and useful.

Relationship with biodiversity, landscape and culture

This package is focused on environmental services which provide benefits of significant policy interest. For this reason landscape and biodiversity feature primarily as inputs to the services, rather than in their own right[3]. This means that the package does not engage with the intrinsic value of nature and biodiversity. In principle the package could include research into 'non-use values' - (value placed on the existence of species and landscapes irrespective of their usefulness to those interviewed), but this is beyond the scope of this version (1.0).

Furthermore benefits have only been included if economic quantification is at least under discussion. For example the contribution of green infrastructure to social cohesion is difficult to quantify but under discussion, whereas the spiritual benefits of access to nature are not[4]. Equally, personal and cultural attachments to particular landscapes may produce important wellbeing benefits, but there is not currently a significant discussion about valuing this economically.

It is important to be clear that in an English context the term 'natural' environment requires significant qualification. For example some of our most valued landscapes are the product of hundreds of years of modification and cultivation and their maintenance is dependent on significant work (Rebanks consulting limited, 2010).

[2] This means that the literature proposes that this human characteristic is cross-cultural which implies a shared root in human evolution.

[3] The importance of biodiversity for providing ecosystem services is complex. Some species provide particularly services directly (eg pollination) in which case it is sensible risk management to retain a range of species which can deliver the service. Other services are provided by whole ecosystems, nevertheless there may be a strong link between a species and ecosystem service - for example many of the properties of blanket bog are dependent on Sphagnum moss. Some ecosystem processes such as productivity or decomposition increase as diversity increases (Potts *et al*., 2010).

[4] Which should not be taken to mean that the spiritual benefits of access to nature are not important, or that it is wise for decision-making to ignore that which is difficult to quantify or subject to uncertainty. The opposite is the case, and work to improve decision aiding frameworks is required. However, the focus of this evidence package is on quantified evidence which can feed in to the currently dominant decision aiding frameworks, particularly economic impact, cost : benefit analysis and value for money assessments.

Natural England works for people, places and nature to conserve and enhance biodiversity, landscapes and wildlife in rural, urban, coastal and marine areas.

www.naturalengland.org.uk