Birmingham
Health Economic Assessment
& Natural Capital Accounts

Revealing the True Value of Council-managed Parks and Green Estate

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By

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I. Executive Summary & Key Messages

In this report, we present a health economic assessment and natural capital accounting exercise to reveal the true value of Birmingham's parks and greenspaces. Birmingham City Council manages an area of over 4,700 ha of parks, greenspaces and allotments. Our assessment reveals that **the benefits provided by these valuable natural capital assets have an indicative value of £11.4 billion** (gross asset value); calculated over a 25 year assessment period. This includes **£4.6 billion in health benefits**. The **total annual benefits add up to £619 million**. The value of Council-managed parks and greenspaces to each resident[1] is approximately £542 every year.

The total net-value (benefits minus costs) of Council-managed natural capital assets is in the order of £11 billion over 25 years or £594 million annually. This means that **each £1 the Council spends on parks and greenspaces returns more than £24 to society**.[2] Please note that the biodiversity value stated below only represents a small fraction of the total biodiversity value. **Biodiversity underpins all other services and benefits which means that they all depend, at least to some extent, on biodiversity.**

The assessment also shows that, from a Council finance perspective only (excluding wider benefits to society), natural capital is a net-asset worth £270 million over 25 years. This is because the presence of Council-managed parks and greenspaces increases annual Council Tax income by approximately £28 million (in addition to direct parks income of £13 million). In contrast, the Council only spends about £26 million on its Parks Services every year. **For every £1 the Council spends on parks and greenspaces, it gains a return of £1.60 in Council Tax and direct parks income.**

This assessment contributes greatly to our understanding of the value of Council-managed parks and greenspaces because it reveals the very significant, but far too often hidden, benefits they provide. Conventional financial accounts only tell part of the story because many 'external' benefits provided by parks and greenspaces are not usually included. This is because a monetary flow is often not observed as one usually does not have to pay for a park visit with all its attached health and wellbeing benefits, for example. And indeed, based on Birmingham City Council's conventional accounts (Parks Budget 2018/19), Council-managed parks and greenspaces are accounted for as a net-liability rather than a net-asset with each £1 spent only returning about £0.50. This shows just how important it is to account for the full value of these important natural capital assets.

If the area of and investment in the City's natural capital declines, overall benefits to society as well as Council Tax income may well decline over-proportionally. Hence, purely relying on

[1] Averaged. The figure includes a limited benefit to residents outside Birmingham such as from climate change regulation and from visits to Council-managed parks and greenspaces by non-residents. The calculation is based on the annual net-value divided by Birmingham's population of 1.14 million (mid-2018 estimate).
[2] Based on stock/capitalised value.

conventional accounting when informing budget decisions affecting parks and greenspaces could easily result in unintended outcomes such as a net-decline in Council finances. This means that other Council services may need to be reduced as well. This is in addition to significant health and wellbeing benefits to society that could be lost when reducing investment in these valuable assets. In light of our findings, green infrastructure of which Council-managed parks and greenspaces form part, should be seen as **critical infrastructure** rather than just a 'good to have'.

Figure I.1 Birmingham Parks & Greenspaces Natural Capital Accounts: Total Asset Value Over a 25 Year Assessment Period

Capitalised/stock values stated in £billions; 2018 prices; central estimates	Adjusted values for aggregation (to avoid double-counting)			
	Total Natural Capital Value	**Health Benefits**	**Direct & Indirect Council Income**	**Conventional Accounts**
Assets				
Property value uplift	£4.75			
Council Tax uplift	£0.48		£0.48	
Physical health benefits	£4.06	£4.06		
Mental health benefits	£0.20	£0.20		
Air quality regulation	£0.30	£0.30		
Recreation	£1.03			
Global climate regulation	£0.22			
Food production from allotments	£0.07			
Biodiversity (non-use benefits only)	£0.04			
Flood risk regulation	£0.03			
Direct parks income	£0.23		£0.23	£0.23
Adjustments	-£0.01		-£0.01	-£0.01
Gross asset value	**£11.41**	**£4.56**	**£0.70**	**£0.22**
Liabilities				
Parks services expenditure	£0.44	£0.44	£0.44	£0.44
Net-Value	**£10.97** to society	**£4.13** in health benefits	**£0.27** to the Council	**-£0.22** as per books
Benefits-Cost Ratio	***26.2 : 1***	***10.5 : 1***	***1.6 : 1***	***0.5 : 1***

Source: ***Author calculation***

The Office for National Statistics set out a strategy to incorporate natural capital into UK Environmental Accounts by 2020. Birmingham City Council has already taken on a pioneering role when assessing the benefits and value of natural capital. This started with assessing the value of ecosystem services provided by Birmingham's green infrastructure as part of Birmingham's Green Living Spaces Plan (Birmingham City Council, 2013; Hölzinger et al.,

2013). Developing natural capital accounts for the parks and greenspaces it manages is the next step to strengthen the evidence base and to inform decisions affecting Birmingham's valuable natural capital assets.

Figure I.2 Birmingham Parks & Greenspaces Natural Capital Accounts: Annual Accounts

Annual(ised) values stated in £millions; 2018 prices; central estimates	Adjusted values for aggregation (to avoid double-counting)			
	Total Natural Capital Value	**Health Benefits**	**Direct & Indirect Council Income**	**Conventional Accounts**
Assets				
Property value uplift	£279			
Council Tax uplift	£28		£28	
Physical health benefits	£193	£193		
Mental health benefits	£10	£10		
Air quality regulation	£14	£14		
Recreation	£61			
Global climate regulation	£13			
Food production from allotments	£4			
Biodiversity (non-use benefits only)	£2			
Flood risk regulation	£1			
Direct parks income	£13		£13	£13
Adjustments	£0		£0	£0
Annual service/benefit value	**£619**	**£218**	**£41**	**£13**
Liabilities Parks services expenditure	£26	£26	£26	£26
Annual net-value	**£594** to society	**£192** in health benefits	**£16** to the Council	**-£13** as per books
Benefits-Cost Ratio	***24.2 : 1***	***8.5 : 1***	***1.6 : 1***	***0.5 : 1***

Source: ***Author calculation***

When conducting this assessment, particular attention has been paid to government guidance as well as an urban natural capital accounts scoping study produced for Defra (Eftec, 2017; ONS and Defra, 2017). Due to uncertainties, values presented here should be regarded as essentially indicative of the magnitude of the benefit. But already the great British economist John Maynard Keynes said that *"it is better to be roughly right than precisely wrong."* And that was exactly the aim of this assessment – to be roughly right by getting as close to the true natural capital value of Council-managed parks and greenspaces as possible rather than being precisely wrong by ignoring their wider health and wellbeing value altogether.

Birmingham Health Economic Assessment & Natural Capital Accounts

Key Findings & Messages

- **Investment in Birmingham's natural capital assets provides good value for money!**
- **Each £1 the Council invests in its parks and greenspaces returns over £24 to society** and £1.60 directly to the Council through direct parks income such as fees and Council Taxes.
- Parks & greenspaces managed by Birmingham City Council have a **total net natural capital asset value in the order of £11 billion** (over 25 years).
- The **annual net-benefit** of Birmingham's parks and greenspaces to society is nearly **£600 million**.
- On average, **each resident receives a benefit from Council-managed parks and greenspaces worth £520 each year**.
- **Physical and mental health benefits provided by Birmingham's Parks and Greenspaces are estimated to add more than 3,300 Quality Adjusted Life Years (QALYs) each year** (83,000 over 25 years).
- The **total health benefits** provided by Council-managed parks and greenspaces are valued at nearly **£4.6 billion** over 25 years.
- **Council-managed woodlands capture more than 350 tonnes of pollutants each year**, avoiding approximately 133 hospital admissions, 28 deaths, and adding 489 life years.
- **Parks and greenspaces managed by Birmingham City Council store more than 573,000 tonnes of carbon**, equivalent to 2.1 million tonnes of CO_2 with a value of £221 million.
- Nearly 7,300 Council-managed **allotments are estimated to produce 2.9 tonnes of food each year** with a value of approximately £4.3 million.
- **This investigation shows just how important it is to account for the true natural capital benefits parks and greenspaces provide.** It also shows how limited and insufficient conventional accounting is in measuring natural capital benefits to society and human wellbeing.

Natural Capital & Natural Capital Accounting

Natural Capital is the sum of our ecosystems, species, freshwater, land, soils, minerals, our air and our seas. These are all elements of nature that either directly or indirectly bring value to people and the country at large. They do this in many ways but chiefly by providing us with food, clean air and water, wildlife, energy, wood, recreation and protection from hazards (HM Government, 2018, p. 19).

Natural Capital Accounts are a series of interconnected accounts that provide a structured set of information relating to the stocks of natural capital and flows of services supplied by them. (ONS and Defra, 2017, p. 3)

II. Acknowledgements

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III. Contents

IV. Tables & Figures

1. Introduction

1.1 Background

In 2011, the UK Government published its Natural Environment White Paper (NEWP) making a commitment to *"put natural capital at the heart of government accounting"* (HM Government, 2011, p. 36). In the academic literature, calls have been made for quite some time to better integrate the value of natural capital and ecosystem services into accounting and decision-making (see e.g. Costanza et al., 1997).

As a response to the NEWP, the Natural Capital Committee was established in 2012 to provide independent advice to the Government on the sustainable use of the nation's natural capital. In its first State of Natural Capital Report, the Natural Capital Committee states:

> *"better accounting for natural capital is a key component of the emerging evidence base to support sensible management of natural capital."*
> (Natural Capital Committee, 2013, p. 27)

The Office for National Statistics (ONS) also published a roadmap which set out a strategy to incorporate natural capital into UK Environmental Accounts by 2020 (ONS, 2012) and subsequently developed national natural capital accounts for different habitat and asset types.[3] The ONS defines natural capital accounts as:

> *"…a series of interconnected accounts that provide a structured set of information relating to the stocks of natural capital and flows of services supplied by them."* (ONS and Defra, 2017, p. 3)

Natural capital can be defined as follows:

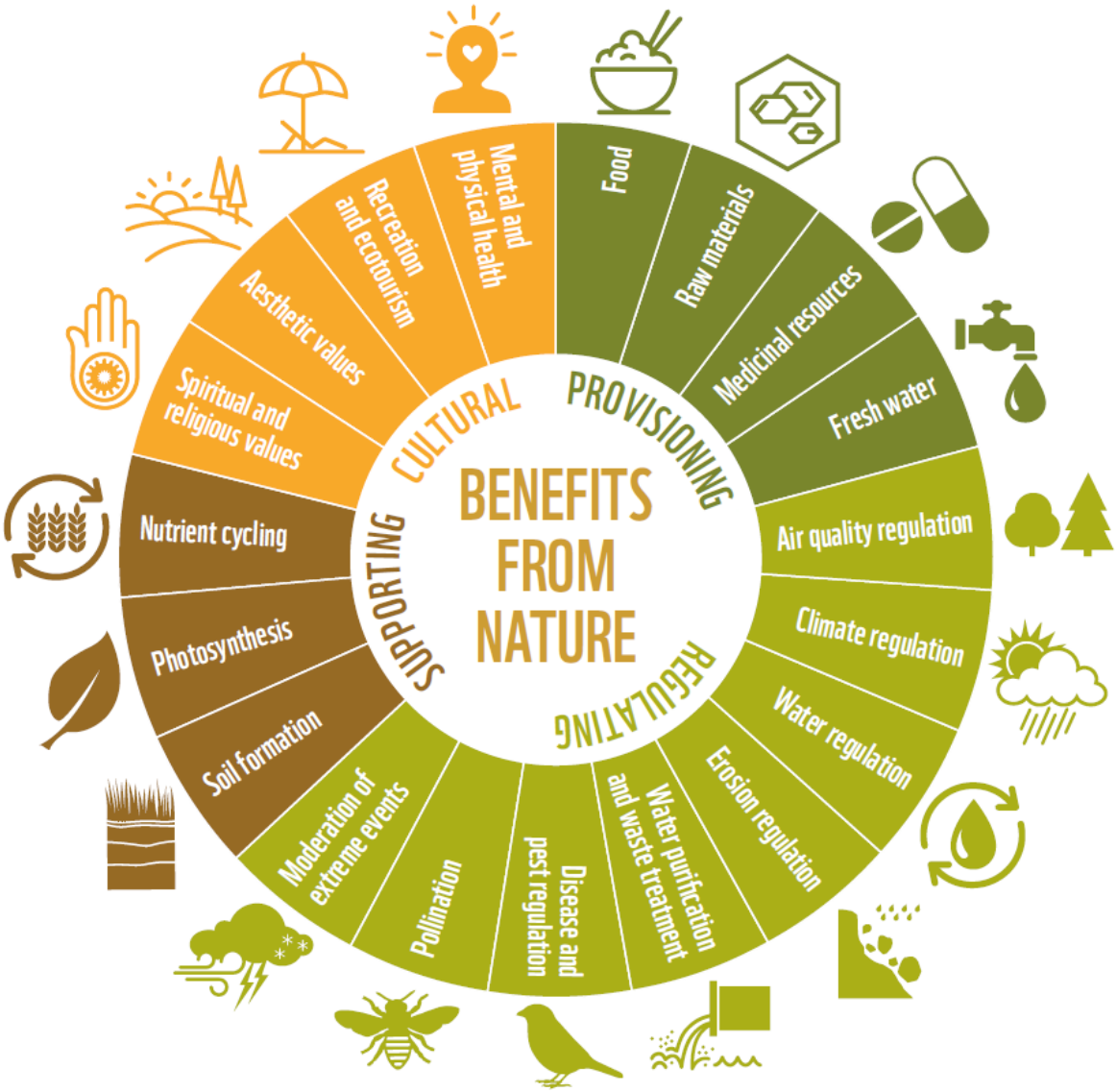
> *"Natural capital is the sum of our ecosystems, species, freshwater, land, soils, minerals, our air and our seas. These are all elements of nature that either directly or indirectly bring value to people and the country at large. They do this in many ways but chiefly by providing us with food, clean air and water, wildlife, energy, wood, recreation and protection from hazards."*
> (HM Government, 2018, p. 19)

The flow of goods and services supplied by natural capital is called ecosystem services which are *"the benefits people obtain from ecosystems"* (Millennium Ecosystem Assessment, 2005, p. V) such as space for recreation including associated health benefits and flood risk mitigation services (see Figure 1.1 for an overview).

[3] See https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/methodologies/naturalcapital for an overview.

Birmingham City Council has taken on a pioneer role in applying advanced methods to assess the value of natural capital and ecosystem services. In 2013, the Council published its Green Living Spaces Plan highlighting the value of ecosystem services provided by the City's green infrastructure (Birmingham City Council, 2013; Hölzinger et al., 2013). The main purpose was to calculate a monetary baseline value for ecosystem services provided by a range of broad habitat types in Birmingham. In early 2015 Birmingham City Council has commissioned the University of Birmingham to further refine natural capital values to better inform the Council's decision-making and reporting by setting up provisional natural capital accounts for the Council's parks and greenspaces; to my knowledge the first city-wide natural capital accounts in the UK. Building on this pioneering work, we update these accounts and expand the scope to capture as much of the value Birmingham's parks and greenspaces provide to people as possible.

Figure 1.1 Ecosystem Services Overview



Source: ***WWF (2018), p. 19***

1.2 Aims and Objectives

Conventional financial accounts only tell part of the story because 'external' benefits provided by natural capital in the form of ecosystem services are not usually included. This is because there is no directly observable flow of money to pay for services such as air quality regulation by the urban forest. The costs for planting and managing forests, however, is usually included in conventional accounts which often leads to the false assumption that natural capital is mainly a liability rather than a valuable asset.

The main aim of this assessment is to calculate the economic net-natural capital value of all parks and greenspaces managed by Birmingham City Council. The objectives are:

1. To establish physical accounts for natural capital stocks over which Birmingham City Council has stewardship responsibility and the ecosystem services that flow from them,

2. To calculate the economic value of these natural capital assets,

3. To calculate the economic value of health benefits provided by relevant natural capital assets,

4. To calculate the property uplift value resulting from natural capital, and

5. To integrate these 'external' natural capital values into Birmingham Parks Department accounts.

1.3 Council-managed Natural Capital Assets

The geographical scope of this assessment is determined by natural capital assets over which Birmingham City Council has stewardship responsibility; i.e. land that is maintained and/or managed by the Council. Maintenance/management is either provided directly through parks services or indirectly through ground maintenance contracts with third parties. Not included in the assessment are natural capital assets such as gravel or gas reserves. The scope of this assessment is limited to green infrastructure natural capital assets only.

These natural capital accounts include a wide range of public (country) parks and playing fields but also other green infrastructure elements such as street vegetation. Please note that some of the land managed by Birmingham City Council such as Lickey Hills Country Park is located outside the city boundaries. Such areas are still included in the assessment scope of this investigation.

Birmingham City Council has a good record of all the natural capital assets it maintains directly through its Parks Services. All data is recorded in its Parks Operations Performance Information (POPI) management system. Spatial land-use data provided by Birmingham City

Council was accompanied by other available data sources including Natural England's Ancient Woodland Inventory and Priority Habitat Inventory, the Forestry Commission's National Forest Inventory, and habitat data provided by EcoRecord, the local environmental record centre for Birmingham and the Black Country.

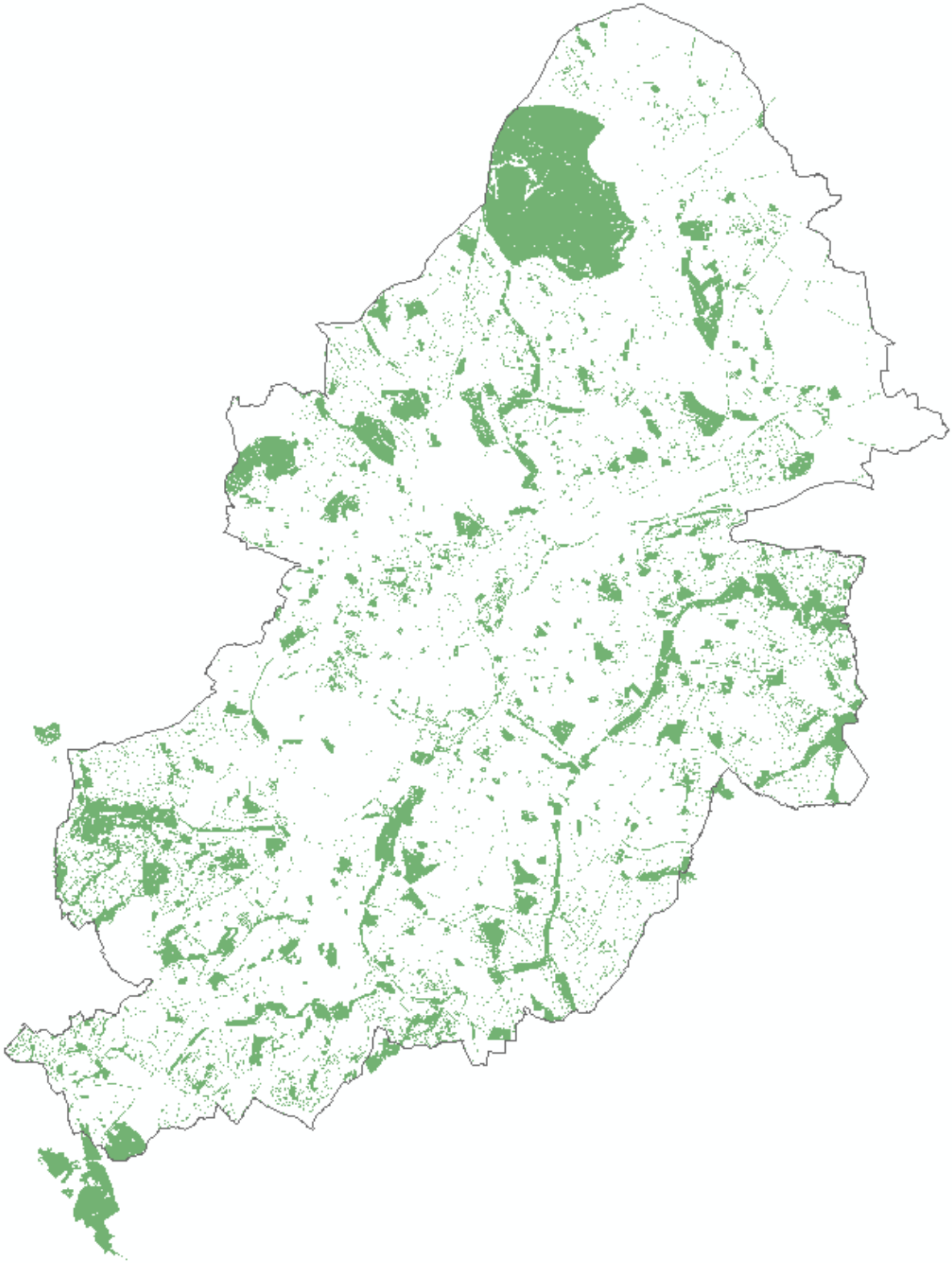
Altogether, an area of 4,745 ha has been included in the assessment scope which is about 17.7% of Birmingham's land area as a whole (see Figure 1.2). The main natural capital asset types included in this assessment are grassland (2,684 ha), woodland (1,068 ha) and heathland & shrub (536 ha). Also included is an area of 259 ha of allotments. The only ecosystem service calculated for allotments is food production. Natural capital assets were classified based on the new UK Habitat Classification Framework (Butcher et al., 2018). A break-down of habitat types included within this assessment is provided in Table 1.1. Following, these habitats are described as natural capital to highlight their asset character.

Table 1.1 Assessed Habitat Types

Broad habitat	Area in ha	Habitat	Area in ha
Grassland	2,684	Acid grassland	63
		Neutral grassland	472
		Modified (improved/amenity) grassland	2,074
		Other/unclassified	75
Woodland and forest	1,068	Broadleaved mixed & yew woodland	1,000
		Coniferous woodland	68
Heathland and shrub	536	Dwarf shrub heath	428
		Hedgerows	25
		Dense scrub	79
		Other/unclassified	3
Wetland	123	Fen, marsh & swamp	123
		Other/unclassified	1
Cropland	259	Horticulture: allotments	259
Urban	2	Flower beds	2
Rivers and lakes	74	Standing open water and canals	74
Total	**4,745**	**Total**	**4,745**

Source: ***Author calculations based on data provided by Birmingham City Council, Natural England, the Forestry Commission and EcoRecord***

Figure 1.2 Geographical Assessment Scope



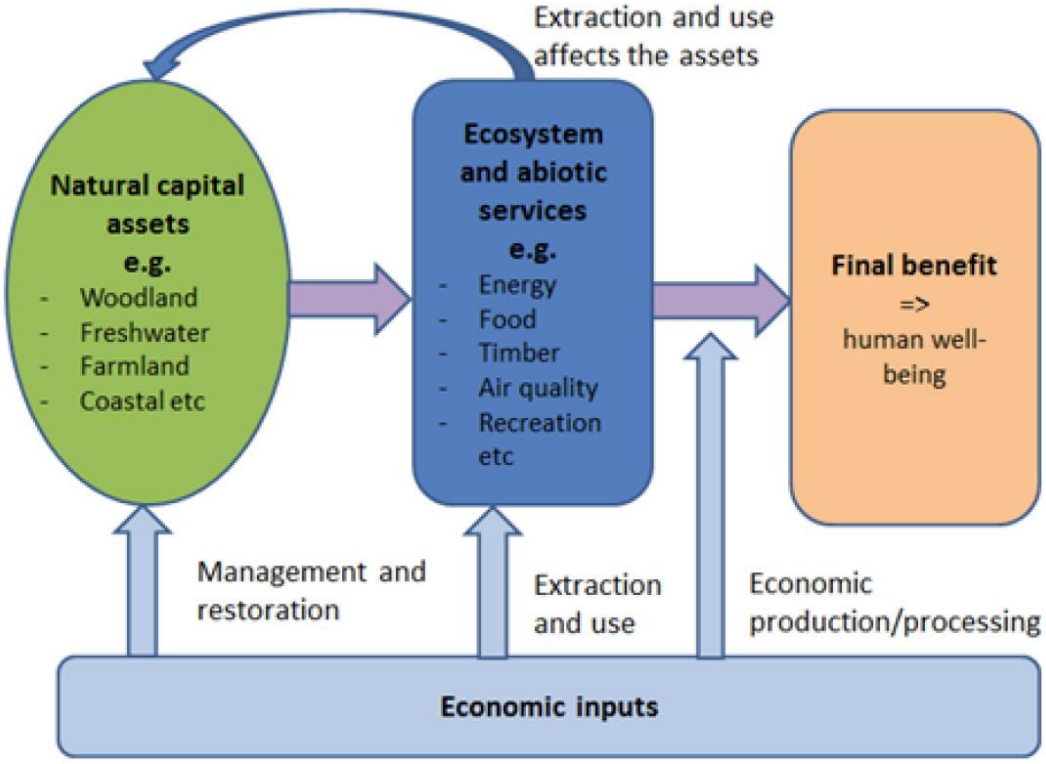
Source: ***Author based on data provided by Birmingham City Council, Natural England, the Forestry Commission and EcoRecord***

1.4 Methodical Approach & Limitations

When developing these natural capital accounts, particular attention has been paid to the 'Principles of Natural Capital Accounting' published by the Office for National Statistics and the Department for Environment, Food & Rural Affair (ONS and Defra, 2017) as well as the scoping study for developing urban natural capital accounts for the UK, produced for Defra (Eftec, 2017). It should be noted that natural capital accounting at all geographical scales is still a developing area of research. The natural capital accounts for Birmingham will contribute to the research field.

Within scope of this assessment, the Total Economic Value (TEV) approach has been chosen. The TEV is a measure of the net value natural capital provides to society. This needs to be distinguished from economic impact which is a measure of economic activity such as for example Gross Development Product (GDP). Employment wages to manage natural capital, for example, contribute positively to economic activity but in a TEV framework it is a cost factor because these wages are required to provide the economic value assuming that without that management the greenspace would not perform ecosystem services to the extent it does with management. Also, economic impact is not necessarily contributing positively to society. If an asset would be destroyed and rebuild exactly as it was then this would only contribute to economic activity but would not necessarily add economic value in terms of TEV or wellbeing.

Figure 1.3 The Links Between Assets, Services & Final Benefits



Source: ***ONS and Defra (2017), p. 4***

To quantify natural capital and ecosystem services values in monetary terms, the benefit transfer approach has been applied. Valuation evidence from research carried out elsewhere or for example at the national scale were transferred to the assessment area (natural capital managed by Birmingham City Council) applying suitable precautions and assumptions as outlined in the following sections. Where possible, adjustments regarding context-specific circumstances and socio-economic variables such as population density have been made to minimise potential transfer-errors.

Carrying out original primary valuation studies was beyond the scope of this study as such studies demand extensive resources and lengthy timescales. The application of the benefit transfer approach can be seen as a practical and cost-effective way of implementing the Ecosystem Approach in decision-making (Defra, 2007).

Even if this methodical approach has been chosen and applied with caution, a range of limitations and caveats apply. For example, related Willingness-To-Pay (WTP) techniques applied in primary valuation studies have their imperfections such as the social desirability bias[4] or a potential inability of survey participants to perceive hypothetical markets and goods. Another limitation may occur from applying the benefit transfer approach. Usually, the study area (where primary valuation studies are conducted) and the policy area (in this case Birmingham City Council-managed natural capital) are not entirely similar. Even if adjustments with respect to socio-economic differences were applied as carefully as possible, a benefit transfer error can never be ruled out.

Further limitations are linked to general scientific uncertainties such as the future impacts of climate change. For these reasons, calculated values should be regarded as essentially indicative of the magnitude of the service.

> *"For high-level ecosystem accounting a degree of uncertainty is acceptable where the main purpose is to estimate orders of magnitude…"*
> (ONS and Defra, 2017, p. 10)

Caveats related to specific assets and services are outlined where relevant in the following sections. To take uncertainties into account within this investigation, a sensitivity analysis has been applied. Using sensitivity analysis, every value is stated as a 'central estimate' with a range (low/high estimate). If not stated otherwise, values are generally stated as 'central estimate'.

The monetary accounts are presented in two different ways. Where possible the stock value has been applied (such as the value of carbon stored in vegetation and soils). Where benefits are occurring as an ongoing service flow through ecosystem services such as for recreation, monetary values are stated both, as annual and capitalised values. Capitalised values

[4] The interviewees may like to make out that they value an ecosystem service more than they actually do

represent the sum of services over a defined time period, discounted to the 'net present value'. Within the scope of this assessment, they were calculated over a timescale of 25 years. The 25 year timescale has been chosen in line with the Government's 25 Year Environment Plan (HM Government, 2018).Please note that the ONS applies a timescale of 100 years for its National Natural Capital Accounts (ONS and Defra, 2017). If the same timescale was also applied here then a higher value would be calculated for capitalised annual flow values.

To calculate the 'net present value' of future benefits, it is common to apply a discount rate. This discount rate is used to convert future benefits (and costs) to present values which make them comparable over different points in time. For the purpose of this investigation, a discount rate of 3.5% has been chosen. This is the Social Time Preference Rate (STPR) or Social Discount Rate recommended in the HM Treasury Green Book (HM Treasury, 2018). An exception is the STPR for quality of life benefits such as the value of added Quality Adjusted Life Years (QALYs) due to health benefits provided by greenspaces. Here, the HM Treasury Green Book recommends applying a discount rate of 1.5%:

> *"The recommended discount rate for risk to health and life values is 1.5%. This is because the 'wealth effect', or real per capita consumption growth element of the discount rate, is excluded. […] health and life effects are expressed using welfare or utility values, such as Quality Adjusted Life Years (QALYs), as opposed to monetary values. The diminishing marginal utility associated with higher incomes does not apply as the welfare or utility associated with additional years of life will not decline as real incomes rise."* (HM Treasury, 2018, p. 103).

For the high estimate of the sensitivity analysis of capitalised values, a discount rate of 3.0% (1.0% reduced rate) has been applied in line with Green Book recommendations. It should also be noted that for capitalised values, a *ceteris paribus* future (everything else remains unchanged) has been assumed. This means that all variables such as population or impacts of climate change were set constant over time.

The available scientific evidence at the time of this assessment did not allow for the full calculation of monetary values for the total range of natural capital assets and ecosystem services. And even if values were calculated for an ecosystem service, they often only cover an element of the ecosystem services. For further information on appropriate natural capital accounting methods see ONS and Defra (2017).

2. Physical & Monetary Natural Capital Accounts

In this section both, a range of ecosystem services and other benefits related to natural capital has been assessed. The following sections outline the specific methods, calculations, physical accounts as well as monetary accounts for each service or benefit.

2.1 Property Value Uplift

The value of a residential property is based on many factors including its size, number of bedrooms, neighbourhood, how centrally located it is etc. One of the factors impacting on property value is also the local availability of natural greenspace such as parks because people have a preference for living in greener areas where they can benefit from its amenity, recreational and health benefits. Hence, people are often prepared to pay a higher price for a property that is located in a greener area with more and better natural capital. This in turn means that the property price contains an implicit natural capital value.

To reveal the implicit natural capital value contained in property prices, the Hedonic Price Method (HPM) can be used. The HPM is used to compare properties with otherwise comparable characteristics such as similar number of bedrooms and similar distance to the next work area, only based on the surrounding natural capital characteristics such as the availability of open greenspace within a certain distance from the property. By doing so, HPM models can estimate the implicit natural capital value by comparing similar properties with and without relevant natural capital features.

> *"[The assessment] assumes that the choice of a house reflects an implicit choice over the nearby environmental amenities so that the value of marginal changes in proximity to these amenities is reflected in house prices."*
> (Mourato et al., 2010, p. 2)

Using the HPM to assess the implicit value of natural capital is based on a sound theoretical foundation and gained increasing popularity in recent years, also when informing benefit transfer (Cho et al., 2008; Mourato et al., 2010; Brander and Koetse, 2011; Saraev, 2012; Tempesta, 2014; ONS, 2018a). Recently, Vivid Economics (2017) for example estimated the value of open spaces in Greater London using evidence from a HPM study (Smith, 2010).

Here, we apply the benefit transfer approach to estimate the property value uplift from natural capital managed by Birmingham City Council using two different primary valuation studies where different methods were applied (Gibbons et al., 2014; ONS, 2018b). The outcomes of both assessments were then averaged to inform our central value estimate.

Property Value Uplift Calculation applying the findings of Gibbons et al. (2014)

The first study we applied for a benefit transfer is a national HPM study conducted by Gibbons et al. (2014) as part of the UK National Ecosystem Assessment (Mourato et al., 2010; UK NEA, 2011a). Gibbons et al. (2014) modelled the amenity value of a range of natural capital-related factors such as proportion of greenspace or distance to the next National Park. This was done by modelling how the price of properties with otherwise similar characteristics (same quality, size, distance to work area etc.) changes due to local greenspace proportion. Gibbons et al. (2014) modelled the amenity value of natural capital for the whole of England. This study was based on a sample of about 1 million housing transactions in England between 1996 and 2008 for which detailed housing and environmental characteristics were available.

To estimate the property value uplift due to natural capital managed by Birmingham City Council, we used the ward-based estimate based on the greenspace proportion within each Census Ward for a benefit transfer. Gibbons et al. (2014) found that property prices in metropolitan areas in England (Model 4) increase by approximately 1.2% (1.1%) for each 1% increase in the greenspace (water) share of a Census Ward.

We used Geographic Information System (GIS) software to estimate the area of Council-managed greenspace (and water) in each ward. We then manipulated Local Land and Property Gazetteer (LLPG) data provided by Birmingham City Council to estimate the number of residential properties in each ward in Birmingham. As LLPG data was only available within the Birmingham boundary, we also used OS AddressBase Plus data for wards outside Birmingham that contain Birmingham City Council-managed greenspace. The average residential property price per ward was measured using Office for National Statistics (ONS) statistics.[5] We used the latest available data from 2015 and adjusted to 2018 prices. This data allowed us to estimate the implicit Council-managed natural capital value contained in property prices in each ward based on greenspace proportion.

Using this method, the greenspace-proportion based property value uplift due to natural capital managed by Birmingham City Council was estimated to be in the order of £13.8 billion. For the purpose of comparison with other annual values in this report, we also annualised this natural capital stock value over our chosen assessment timescale of 25 years, applying a discount rate of 3.5%. 25 years reflects the standard mortgage duration in the UK. The estimated annualised property uplift value is £810 million.

[5] HPSSA Supplementary Dataset 8 - Mean Price Paid by ward

Property Value Uplift Calculation applying the findings of ONS (2018c)

In addition, also a study conducted by the Office for National Statistics (ONS, 2018b) has been chosen for a benefit transfer. Although it should be noted that the methodical approach chosen here differs significantly from the approach used by Gibbons et al. (2014).

The ONS (2018c) study includes information from over 2.6 million properties sold in Great Britain between 2009 and 2016. In contrast to the Gibbons et al. (2014) analysis, the ONS (2018c) study assesses the difference in property prices depending on if there is a functional greenspace (and/or bluespace) available within 200m from the property. Hence, it is not based on the amount of greenspace within the local area but only if there is a greenspace (bluespace) accessible within 200m.

To apply this study for a benefit transfer to Council-managed functional greenspaces and bluespaces, a comprehensive GIS analysis has been conducted. As part of this analysis, all functional greenspaces and bluespaces managed by the Council have been split into size categories (small, medium, large and very large functional greenspace/bluespace). This is because larger functional greenspaces (bluespaces) accessible within 200m of a property increase its value to a greater extent. For functional greenspace, the price premium ranges from 0.5% (small) to 1.5% (very large) and for bluespaces from 0.9% (small) to 3.6% (very large). In the next step, all properties within a 200m buffer around functional greenspaces and bluespaces were identified using LLPG and OS AddressBase data.

To calculate the implicit natural capital value of each property located within 200m from a functional greenspace (bluespace), ONS property price statistics aggregated at the Lower Super Output Area (LSOA) level were used. The average property prices for the years 2017 and 2018 were used to inform our benefit transfer. In case property sales statistics were not available for these years, older property sales have been used and adjusted to 2018-prices.

To calculate the natural capital value implicit in properties located within 200m of a Council-managed greenspace and/or bluespace, the relevant implicit natural capital price premium attached to a small (medium, large and very large) functional greenspace was applied. This was done by multiplying the average property price at LSOA level by the expected implicit natural capital value (e.g. 0.5% for a small functional greenspace) for each identified property. If properties are located within 200m of 2 or more functional greenspaces (bluespaces), only the highest price premium has been applied for greenspaces and bluespaces, respectively. This means that, if a property is located within 200m of a small and a large functional greenspace, the (higher) implicit natural capital value has been applied.

The total natural capital value was then calculated by adding up all implicit price premiums for all properties located within 200m of a functional greenspace and/or bluespace. This analysis resulted in a total property price uplift of £493 million due to functional greenspace and £52 million due to bluespace. The total property price uplift due to functional

greenspaces and bluespaces within 200m of properties is estimated to be £544 million. This results in a value of £31 million if annualised over a timescale of 25 years.

Aggregation of results

One can easily see that the estimates based on Gibbons et al. (2014) (£13.8 billion) and the estimates based on ONS (2018c) (£0.5 billion) differ significantly. It was expected that the ONS outcomes would be lower because the model design is more limited in scope, but not necessarily by such a significant magnitude.

The ONS study only accounts for functional greenspace (bluespace) within 200m from the property. Here, it does not make a difference if there is 1 ha or 100 ha of functional greenspace within 200m of the property. Also, it does not matter if there is one greenspace or for example 3 greenspaces within 200m of the property. Nor does it matter if the distance to the next greenspace is 1m or 200m. Furthermore, no implicit natural capital value is attached to any properties that do not have a Council-managed functional greenspace or bluespace present within 200m, even if they may well benefit from greenspace that is 201m away.

Because Gibbons et al. (2014) account for the greenspace (bluespace) proportion within the Ward a property is located, we assume that it captures more of the natural capital value than the distance-threshold based ONS (2018c) study. We assume that the ONS (2018c) study design relates more to recreation because it looks at if there are recreational opportunities within short proximity or not. In contrast, the Gibbons et al. (2014) study also indicates amenity values because it captures the general 'greenness' of an area as it assesses local greenspace proportion.

Also given that the Gibbons et al. (2014) study is peer reviewed we place more trust in these estimates. But applying appropriate caution, we decided to apply the average of the Gibbons et al. (2014) based and the ONS (2018c) based estimates as central estimate which is in the order of £7.2 billion or £421 million when annualised. To acknowledge the wide range of value estimates, we adopt the ONS (2018c) figure of £544 million as lower sensitivity analysis estimate and the Gibbons et al. (2014) figure of £13.8 billion as higher sensitivity analysis estimate, respectively. The findings are summarised in Figure 2.1. Please note that overlaps with other calculated benefits are likely. That is why the figures presented here in Figure 2.1 have been adjusted for aggregation (see Section 2.10).

Figure 2.1 Property Value Uplift

Physical Accounts			
			No of properties
Assessed residential properties (Gibbons et al. 2014)			472,863
Residential properties within 200m of… (ONS 2018)			
…Small (<0.65ha) functional greenspace			42,167
…Medium (0.65ha-2.05ha) functional greenspace			46,515
…Large (2.05ha-5.76ha) functional greenspace			69,495
…Very large (>5.76ha) functional greenspace			98,241
…Small (<0.02ha) bluespace			3,245
…Medium (0.02ha-0.09ha) bluespace			4,431
…Large (0.09ha-0.35ha) bluespace			2,358
…Very large (>0.35ha) bluespace			5,310
Monetary Accounts			
Annualised Stock Value		*High*	*Low*
Property Value Uplift	**£421,160,000**	*£810,403,000*	*£31,917,000*
Natural Capital Stock Value		*High*	*Low*
Property Value Uplift	**£7,184,300,000**	*£13,824,150,000*	*£544,449,000*
Stock value, 2018 prices; annualised central value discounted at 3.5% over 25 years; High/Low : Sensitivity analysis.			

Source: ***Author calculation based on Gibbons et al. (2014) and ONS (2018c).***

2.2 Council Tax Uplift

The amount of Council Tax residents pay on domestic property is based on a band (A to H) which itself is based on the property value. This means that, because there is an implicit natural capital value in the property value (see Section 2.1), there is also an implicit natural capital element in the Council Tax paid by residents to fund public services. These services include the management of parks and greenspaces. Basically, if natural capital in Birmingham declined, Council Tax income would also decline. The question is by how much.

In its budget for 2017/18, Birmingham City Council estimated the Council Tax income to be £308.5 million (Birmingham City Council, 2017a). To estimate the amount of Council Tax attributable to natural capital managed by the Council, we multiplied the total estimated Council Tax income of £308.5 million by the overall property price uplift due to Council-managed natural capital which is 9.2% (central estimate). The assumption underlies that there is a linear correlation between property prices and Council Tax income and that the natural capital would not exist if it was not managed by Birmingham City Council.

The analysis revealed that £28 million of the Council Tax income can be attributed to natural capital in 2017/18. In other words, without the natural capital (parks, playing fields etc.) managed by Birmingham City Council, the Council's income from Council Tax would be reduced by £28 million. If capitalised over 25 years, the Council Tax uplift is valued at £482

million. The range of the sensitivity analysis is based on the sensitivity range applied for the property price uplift (see Section 2.1). The results are summarised in Figure 2.2 below.

Figure 2.2 Council Tax Uplift

Monetary Accounts			
Annual Natural Capital Value		*High*	*Low*
Council Tax Uplift	**£28,237,000**	*£54,334,000*	*£2,140,000*
Capitalised Natural Capital Value		*High*	*Low*
Council Tax Uplift	**£481,675,000**	*£974,508,000*	*£36,503,000*

Present value, 2018 prices; capitalised central value discounted at 3.5% over 25 years; High/Low: Sensitivity analysis.

Source: ***Author calculation based on Gibbons et al. (2014), ONS (2018c) and Birmingham City Council (2017a).***

The annual Council Tax uplift of £28.2 million due to natural capital is much higher than what the Council spends on parks services which was only 11.7 million as per 2017/18 budget (Birmingham City Council, 2017a). Hence, reducing investment in parks services and natural capital management would mean that in the medium and long-term, the Council would have less funding for public services such as parks but also, for example, fire services or childcare. Additional investment into natural capital, on the other hand, is likely to increase Council Tax income over time.

2.3 Health Economic Assessment

The availability of accessible greenspace close to where people live is increasingly being recognised to improve people's health by providing space for physical activity (Coombes et al., 2010). About three out of four UK adults agree that greenspaces are important for their general health (Kuppuswamy, 2009). Exposure to greenspace and natural capital is associated with a wide range of positive health effects. This, in turn, helps prevent the onset of diseases such as obesity, diabetes, heart diseases and strokes.

Several studies have shown that regular park users are healthier than their counterparts. This applies for a range of measures such as diastolic and systolic blood pressure, depression score and perception of general health (Ho et al., 2003). A recent review by Public Health England (2017) found:

> *"There is a very significant and strong body of evidence linking contact and exposure to the natural environment with improved health and wellbeing."* (Public Health England, 2017, p. 38)

The review by Public Health England (2017) suggests that:

- Cleaner air can encourage the older population to be more active.

- Increased air pollution is linked with an increased risk of developing chronic conditions such as type II diabetes, poor birth outcomes, cancer, worsened respiratory outcomes and childhood mortality,

- Access to, and engagement with, the natural environment is associated with numerous positive health outcomes including improved physical and mental health and the reduced risk of cardiovascular disease, risk of mortality and other chronic conditions.

- There is also consistent evidence that having access to recreational infrastructure such as parks is associated with a reduced risk of obesity among adolescents and an increase in physical activity.

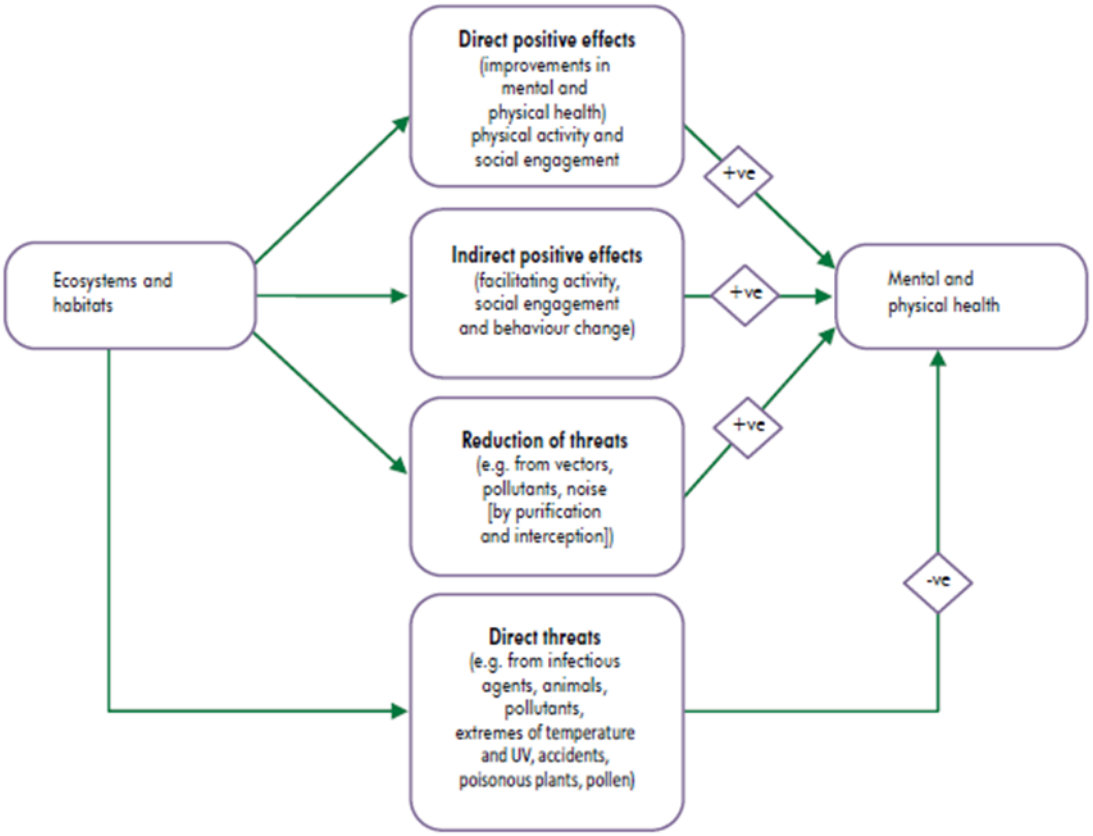
- Evidence also suggests that improving the appearance of parks can increase usage and increase physical activity among children and older adults.

The availability of greenspace close to where people live is also known to reduce mortality rates:

> *"An extensive and robust body of evidence suggests that living in greener environments (e.g. greater percentage of natural features around the residence) is associated with reduced mortality. Reduced rates of mortality have been found for specific population groups including men, infants and lower socio-economic groups. There is evidence to suggest that health inequalities in mortality may be reduced by greener living environments."* (Defra, 2017, p. 2)

In this section we are quantifying the monetary value for a range of significant positive health benefits from greenspaces; in particular physical health, mental health and air quality regulation. However, it needs to be stressed that this only covers part of the overall health benefits of natural capital (see Defra, 2017 for an overview). It should also be noted that almost all ecosystem services provided by natural capital have some impact on human health (see Figure 2.3).

Figure 2.3 Health Benefits and Threats from Ecosystems



Source: ***Adapted from Pretty et al. (2011, p. 1157)***

Especially when health is understood as a good state of human wellbeing then health is directly linked to all ecosystem services. This is in line with the definition of health by the World Health Organisation:

> *"Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." (WHO, 1948, p. 1)*

The WHO's definition of health has also been adopted by the UK National Ecosystem Assessment (Church et al., 2011).

2.3.1 Physical Health Benefits

There is consistent evidence that having access to recreational infrastructure, such as parks and playgrounds, is associated with reduced risk of obesity among adolescents and increase in physical activity (Public Health England, 2017).

To assess the value of physical health benefits greenspaces managed by Birmingham City Council provides, we adapted[6] the approach developed by White et al. (2016). A similar approach was also used to develop urban natural capital accounts for the UK for Defra and the ONS (Eftec, 2017; ONS, 2018a).

The first step was to identify 'active visits' to greenspaces managed by Birmingham City Council. Active visits are defined here as visits of at least moderate physical intensity such as walking, for the duration of at least 30 minutes. We used Natural England's Monitor of Engagement with the Natural Environment (MENE) survey data for 2009/10 to 2013/14[7] to estimate the number of active visits to the natural environment in Birmingham. To do so, we identified all visits that meet all of the following three criteria:

1. The visit had a duration of at least 30 minutes. This is the threshold used by Beale et al. (2007) for estimating the increase in Quality Adjusted Life Years (QALYs). The visit duration is recorded in the MENE survey. Please note that the Chief Medical Office suggests that all moderate physical activities of at least 10 minutes count towards a person's activity goal.[8] Hence, our threshold of 30 minutes is a conservative assumption.

2. The activity during the visit was of moderate intensity of at least 3 METs (Metabolic Equivalence of Task). The MET is not recorded in the MENE survey but activities during the visit are. We only included visits with an activity equivalent to at least 3 METs[9] (Ainsworth et al., 2011; Elliott et al., 2015).

3. The visit was by a person who meets general physical activity guidelines of at least 30 minutes of at least moderate exercise; at least 5 times a week (Department of Health, 2004). In MENE, people are asked if they meet these requirements. However, also included were visits by individuals who stated they did not meet the requirements but did natural visits at least five times within the last week at the appropriate intensity level and for the appropriate duration. The assumption underlies that the week when people were surveyed is a representative week of the year.

[6] The adaptation mainly relates to applying an updated value for a Quality Adjusted Life Year (QALY) in line with HM Treasury Green Book (2018) recommendations.
[7] The MENE survey is ongoing but latest data does not include all relevant information to inform this assessment. This is why older waves have been used. The assumption underlies that these waves are representative for visits to date as well.
[8] https://www.gov.uk/government/publications/uk-physical-activity-guidelines
[9] Relevant activities recorded in MENE that meet the moderate intensity requirement include: Fieldsports (i.e. hunting), horse riding, off road cycling/mountain biking, playing with children, road cycling, running, visiting an attraction, walking without a dog and walking with a dog

This method allowed us to estimate all 'active visits' by 'active people' to greenspaces in Birmingham. The assumption underlies that there can be more than one activity per visit which means that visitors can be 'active' more than once per visit.

To estimate the number of visits to greenspaces managed by Birmingham City Council, an area-based adjustment was undertaken. We divided the total number of visits by the area of accessible greenspace (public and private open space/playing fields as a proxy) within Birmingham and multiplied the result by the area of greenspace managed by Birmingham City Council (public open space/playing fields as a proxy) in addition to Council-managed greenspace outside the Birmingham boundary. The estimated annual number of active visits to Council-managed greenspace by active people is 15.7 million.

Beale et al. (2007) used Health Survey for England data to estimate that 30 minutes a week of moderate-intense physical activity, if undertaken 52 weeks a year, would be associated with a QALY increase of 0.010677 per individual per year. This means that 4,870 active visits by active people are required to add one QALY per annum. Hence, the estimated 15.7 million active visits by active people to greenspaces managed by Birmingham City Council have an estimated annual benefit of adding 3,215 QALYs. The assumption underlies that the exercise would not have taken place without the availability of the greenspace.

For the purpose of this assessment we assume that the relationship between physical activity and QALYs is both, cumulative and linear (Beale et al., 2007). Although, in reality a non-linear relationship may occur where additional exercise still results in increasing QALY benefits, but at a decreasing rate (Woodcock et al., 2011). We also assume that the same QALY increase of the English population also applies to the visitors of Birmingham's greenspaces. Considering that Birmingham's population has higher cardiovascular disease rates than the English average, the positive effects of 'green exercise' to this population sub-sample are likely to be greater than that indicated by Beale et al. (2007). Furthermore, the physical health benefits to children under 16 were not accounted for because they are not included in the MENE survey results. Therefore, the actual physical health benefits of Council-managed parks and greenspaces are probably higher than those presented here.

Referring to the Green Book (HM Treasury, 2018), the WTP per QALY is £60,000:

> *"The current monetary WTP value for a QALY is £60,000. Further information on the basis for the value of a QALY can be obtained by contacting the Department of Health and Social Care."* (HM Treasury, 2018, p. 73).

Applying this WTP of £60,000 for a QALY[10] results in an estimated value of 'green exercise' in greenspaces managed by Birmingham City Council of £193 million or £3.3 billion capitalised. Here, a reduced discount rate of 1.5% (1.0% for the high estimate) has been applied for

[10] Please note that in the original study conducted by White et al. (2016), a value per QALY of £20,000 has been applied.

calculating the capitalised values (see Section 1.4). The range of the sensitivity analysis is based on the margin of error of the MENE results[11] plus a 20% range to account for uncertainties in the evidence base.[12]

The analysis shows that 'green exercise' in Council-managed parks and greenspaces contributes significantly to people's health and wellbeing. It is difficult, however, to say if the existence of the greenspaces is essential for the exercise or if people would exercise in other environments instead if the greenspace was not available. On the other hand, visits of shorter duration (<30 minutes), low intensity (<3 METs) and/or by otherwise not so active people (e.g. only 4 times of relevant exercise a week) were not included in the assessment although they are still likely to have some health benefit. Neither included are the potential 'excess-benefits' of green exercise for e.g. vigorous intensity activities (≥6 METs) such as running or those of exercises significantly longer than 30 minutes which may well have benefits over and above the applied 0.0002053231 QALY increase per visit. More research on these aspects is required.

Figure 2.4 Physical Health Benefits

Physical Accounts			
		Annually	Over 25 years
'Active' visits to Natural Capital by 'active' people		15,659,999	391,499,974
Added Quality Adjusted Life Years (QALYs)		3,215	80,384
Monetary Accounts			
Annual Natural Capital Value		*High*	*Low*
Physical Health Benefit	**£192,922,000**	*£247,475,000*	*£138,368,000*
Capitalised Natural Capital Value		*High*	*Low*
Physical Health Benefit	**£4,057,218,000**	*£5,504,676,000*	*£2,909,943,000*
Present value, 2018 prices; capitalised central value discounted at 1.5% over 25 years; High/Low : Sensitivity analysis.			

Source: ***Author calculation.***

2.3.2 Mental Health Benefits

More than 40% of English adults state that they have had a mental disorder at some point with 13% of adults reporting that they had a mental disorder diagnosed in the last 12 months (Stansfeld et al., 2016). A consistent body of evidence suggests that exposure to natural environments improves mental health. A recent review of the links between natural environments and human health for Defra by the European Centre for Environment and Human Health and the University of Exeter Medical School found that:

> *"There is relatively robust evidence of a relationship between mental health and wellbeing outcomes, including lower rates of stress, fatigue, anxiety and depression, and exposure to natural environments."* (Defra, 2017, p. 11)

[11] Based on the Rule of Thumb: 1.35 * (1/(SQRT sample size)).
[12] A 20% range for the sensitivity analysis was chosen by the authors.

Gascon et al. (2015) for example found evidence of a causal relationship between surrounding greenspace and mental health as part of a systematic review of the relationship between long-term exposure to natural environments and mental health. A recent report by Public Health England (2017) also found evidence indicating that participation in physical activity in a natural setting is associated with more improved mental health outcomes than participation in physical activity in an indoor setting.

To estimate the monetary value of mental health benefits provided by greenspace managed by Birmingham City Council, we used evidence provided by White et al. (2013) in combination with cost estimates provided by Public Health Birmingham and the Centre for Mental Health (2010). A comparable approach has been used to estimate the mental health benefits of public greenspaces in London (Vivid Economics, 2017). It should be stressed, however, that this is an experimental approach and further research is required to strengthen both, data and methods.

The Centre for Mental Health (2010) estimates the economic and social costs of mental health in England to be in the region of £105.2 billion in 2009/10 (nominal). This figure covers the associated costs for health and social care (Local Authority social services, GP consultations, drug prescriptions and NHS hospital and community health services), productivity losses due to mental health problems and the direct impact on life quality based on Quality Adjusted Life Years (QALYs) lost due to mental health problems. For details on methods and calculations see Centre for Mental Health (2003).

In a first step, we calculated the average social and economic costs of mental health per household in Birmingham. To do so, cost estimates for England provided by the Centre for Mental Health (2010) were adjusted to 2018 prices. Furthermore the WTP for a Quality Adjusted Life Year (QALY) was updated based on HM Treasury (2018).[13] This resulted in an average annual cost estimate of £7,754 per English household for mental health. This value consists of £1,199 health and social care costs, £1,706 economic output losses (for example because of sickness absence), and £4,936 in human costs related to QALYs lost.

In a second step, the Centre for Mental Health (2010) health and social care cost estimate of £1,199 was adjusted to £1,481.[14] The latter figure represents the average health and social care cost estimate for Birmingham, kindly provided by Public Health Birmingham.[15] Combined with the Centre for Mental Health (2010) cost estimates for economic output

[13] The Centre for Mental Health (2010) calculated the quality of life benefits based on a value of £30,000 per QALY whilst Department of Health and Social Care recommends using a value of £60,000 instead (HM Treasury, 2018). See also Section 2.3.1 of this report.

[14] Unfortunately, it is not clear which diseases and treatment costs are included in the Centre for Mental Health (2010) estimates. This means that we cannot meaningfully compare the English and the Birmingham figures because it is not clear if they are based on the same cost elements.

[15] The authors would like to thank Duncan Venom from Public Health Birmingham for providing Birmingham-specific figures.

losses and human costs, the total average annual mental health costs per household in Birmingham were estimated to be £8,124.

In a next step, the impact of local greenspace proportion on mental health outcomes in Birmingham was estimated. White et al. (2013) modelled the impact of local urban greenspace proportion on self-reported mental health using British Household Panel Survey (BHPS) data from over 10,000 individuals. They found that a 1% increase in greenspace[16] (water) in terms of land-use share at the Lower Super Output Area (LSOA) level decreases the General Health Questionnaire (GHQ) score by 0.0023 (0.0007). The GHQ score indicates the level of mental distress on a scale from 0 (very low mental distress) to 12 (very high mental distress).

To estimate the impact of greenspace (water) proportion on mental health in Birmingham we used Geographic Information System (GIS) software to estimate the area of Council-managed greenspace (and water) in each Census Ward.[17] Based on White et al. (2013), we calculated the expected GHQ-based self-reported mental health improvement per household based on the greenspace (water) proportion in each assessed ward.

We then used GIS software to manipulate Local Land and Property Gazetteer (LLPG) data provided by Birmingham City Council to estimate the number of residential properties in each ward in Birmingham. As LLPG data was only available within the Birmingham boundary, we also used OS AddressBase Plus data for wards outside Birmingham that contain Birmingham City Council-managed greenspace (see Figure 1.2). This allowed us to calculate the self-reported mental health improvement due to greenspace (water) for each assessed household.

To calculate the mental health benefits provided by Council-managed parks and greenspaces in monetary terms, we multiplied the average mental health costs per household in Birmingham (£8,124) by the relative contribution of local greenspace (water) proportion in each ward towards avoiding these costs. The assumption underlies that mental health costs and self-reported mental health state as per GHQ are directly correlated and linear. This means that if the availability of local greenspace would improve the self-reported GHQ score of a household by 10% (1.2 scores), an annual value of £812 would be attributed.

Applying this method for all households in wards with Council-managed greenspace and/or water results in an estimated total annual mental health benefit by Council-managed parks and greenspaces in the region of £10 million (£201 million capitalised). The findings are

[16] Here, I'm using the more conservative figure for greenspace excluding domestic gardens as the present assessment does not include gardens.

[17] Here, greenspace proportion was aggregated at the Census Ward level rather than the LSOA level as in the White et al. (2013).

summarised in Figure 2.7. The sensitivity analysis range is based on the standard error reported in White et al. (2013) for greenspace.[18]

Figure 2.5 Mental Health Benefits

Physical Accounts			
		Annually	Over 25 years
Added QALYs (for quality of life benefits only)		105	2,616
Monetary Accounts			
Annual Natural Capital Value		*High*	*Low*
Health and social care cost savings	**£1,884,000**	*£2,453,000*	*£1,314,000*
Economic output gains	**£2,170,000**	*£2,826,000*	*£1,514,000*
Quality of life benefits	**£6,279,000**	*£8,177,000*	*£4,381,000*
Total Mental Health Benefit	**£10,333,000**	*£13,457,000*	*£7,209,000*
Capitalised Natural Capital Value		*High*	*Low*
Health and social care cost savings	**£32,135,000**	*£44,002,000*	*£22,420,000*
Economic output gains	**£37,022,000**	*£50,694,000*	*£25,830,000*
Quality of life benefits	**£132,053,000**	*£181,895,000*	*£92,130,000*
Total Mental Health Benefit	**£201,210,000**	*£276,592,000*	*£140,379,000*

Present value, 2018 prices; capitalised central value discounted at 3.5% (1.5% for quality of life benefits) over 25 years.

Source: ***Author calculation.***

Due to the experimental nature of this approach, outcomes should be treated with some care. Limitations of this assessment include the simplistic definition of greenspace, that trends in wellbeing such as anticipation and adaptation effects before and after moving to/away from greenspace were not accounted for, and that not all potential explanatory variables could be controlled for in the assessment by White et al. (2013). It should also be stressed that the mental health cost estimates provided by the Centre for Mental Health (2010) are of provisional nature - especially with respect to the human costs (Centre for Mental Health, 2003).

The assumption of a direct and linear correlation between healthcare costs/social wellbeing on the one hand and self-reported mental distress on the other also needs to be tested through further research. This assessment gives us a rough indication of the mental health value provided by Council-managed natural capital rather than an exact answer.

[18] In White et al. (2013), the standard error is only reported for greenspace including domestic gardens and for water. Given the dominance of greenspace, the standard error for greenspace has been used; applied in terms of percentage change.

2.3.3 Air Quality Regulation

Complex vegetation and particularly trees have a positive effect on the regulation of air quality. The main sources for pollution are vehicle exhaust, industry and intensive agriculture (van Oudenhoven et al., 2012).

The whole of Birmingham has been designated an Air Quality Management Area (AQMA) under the Environment Act 1995, which means that Birmingham City Council has a duty to monitor and report on levels of nitrogen dioxide (NO2), fine particulates (PM_{10} and $PM_{2.5}$) and sulphur dioxide (SO_2). Where those limits are breached or will be breached, the Council has to produce an Air Quality Action Plan to bring the air quality under the limits. The latest annual status report shows that levels of PM_{10}, $PM_{2.5}$ and SO_2 did not exceed allowed levels, but level of NO_2 need to be reduced (Birmingham City Council, 2017b). But it should be noted that even pollution levels below the allowed thresholds can cause significant harm to human health and wellbeing.

Trees and other vegetation absorb, through physical deposition as well as chemical reactions, deleterious pollution which are responsible for major illnesses such as respiratory ailments, heart disease and cancer (McPherson et al., 1994). Research carried out in New York also suggests that a high tree density significantly reduces asthma prevalence in very young children (Lovasi et al., 2008).

The species selection as well as the location and management of trees and woodland have a significant impact on the ability to regulate air quality. In general, trees and vegetation can capture, for example, more fine dust if located close to the source of fine dust emissions (van Oudenhoven et al., 2012).

> *"...increasing deposition by the planting of vegetation in street canyons can reduce street-level concentrations in those canyons by as much as 40% for NO_2 and 60% for PM."* (Pugh et al., 2012, p. 7692)

But trees can also worsen local air quality, depending on their location. Trees directly located along busy streets creating a closed canopy 'roof' can trap pollutants because the polluted air from traffic exchanges slower. This can have a negative effect on localised air quality along busy streets (Buccolieri et al., 2009). Therefore it can at times be appropriate to locate trees further away from the carriageway to gain the best outcomes (Woodland Trust, 2012).

To calculate the value of air quality regulating services provided by natural capital managed by Birmingham City Council, evidence provided by Jones et al. (2017) who developed valuation estimates of air pollution removal at the national scale for the Office for National Statistics (ONS) were used. Jones et al. (2017) used the EMEP4UK atmospheric chemistry and transport model developed by the Centre for Ecology and Hydrology (CEH) which models

pollutant concentrations directly from emissions, and dynamically calculates pollutant transport and deposition, taking into account meteorology and pollutant interactions.

The ONS (2018b) provides 2015-based estimates for both, pollutant removal as well as corresponding values based on avoided hospital admissions, avoided life years lost[19] and avoided deaths at the regional level. For Birmingham as a whole, the benefits of air quality regulation by natural capital was estimated to be in the region of £19.4 million in 2015 (adjusted to 2017 prices). Most of this value (£16.5 million) is attributed to the removal of over 9 tonnes of fine particles ($PM_{2.5}$).

To estimate the pollution removal and air quality benefits provided by natural capital managed by Birmingham City Council, the area of woodland has been used as a proxy. At the GB-scale, 97% of the urban air quality regulation benefits is attributed to woodland. GIS software was used to estimate the total area of woodland in Birmingham (1,583 ha) as well as the area managed by the Council[20] (1,147 ha). This results in an air quality regulation health benefit provided by Council-managed natural capital of £14.5 million annually or £304 million capitalised. A break-down by pollutant is provided in Figure 2.6.

We also estimated the hospital admissions, life years lost and deaths avoided due to Council-managed green infrastructure. Because these figures are not stated at the regional level we had to base estimates on national estimates which are provided in Jones et al. (2017). The assumption underlies that the proportions between avoided hospital admissions, life years lost and deaths per pollutant are similar at the GB and the Birmingham level. A break-down at the Birmingham level was not available. Assessments based on the benefit per pollutant resulted in an estimated annual 133 avoided hospital admission, 489 life years gained and 28 avoided deaths. As standard errors or other figures to inform a sensitivity analysis were not reported in Jones et al. (2017), we applied a sensitivity analysis range of 20%.

Please note that annual values are likely to be underestimated. This is because non-woodland trees such as street-, park-, and highway trees are not included in the valuation. Furthermore, the value of removed PM_{10} and ammonia could not be quantified in monetary terms.

Please also note that, as for other capitalised values in this report, a *ceteris paribus* assumption applies. This means that all other variables such as population are assumed to remain constant over time. However, unlike for most other ecosystem services and health benefits, for air quality regulation it is expected that the value of the benefit will decline over time. This is mainly because it is expected that the pollution concentration will decline over time. There is less pollution for the vegetation to remove, so natural capital provides less

[19] Not to be confused with Quality Adjusted Life Years (QALY) as used elsewhere in this study. For details see Jones et al. (2017).

[20] This figure also includes areas of woodland outside the Birmingham boundary. The assumption underlies that the same per-ha value applies as it is located in close proximity to Birmingham.

service (Jones et al., 2017). However, to be consistent across this study, we keep the *ceteris paribus* assumption unchanged.

Figure 2.6 Health Benefits from Air Quality Regulation

Physical Accounts			
		Annually	Over 25 years
Tonnes of pollutants captured (dry deposition of pollutants)			
...Fine particles (PM2.5)		7	169
...Sulfur dioxide (SO2)		38	938
...Nitrogen dioxide (NO2)		62	1,557
...Ozone (O3)		220	5,502
...Fine particles (PM10)		10	251
...Anhydrous ammonia (NH3)		18	440
Avoided hospital admissions (respiratory & cardiovascular)		133	3,334
Avoided life years lost		489	12,218
Avoided deaths		28	708
Monetary Accounts			
Annual Natural Capital Value		*High*	*Low*
Fine particles (PM2.5)	**£12,342,000**	*£14,810,000*	*£9,873,000*
Sulfur dioxide (SO2)	**£16,000**	*£20,000*	*£13,000*
Nitrogen dioxide (NO2)	**£1,432,000**	*£1,719,000*	*£1,146,000*
Ozone (O3)	**£667,000**	*£800,000*	*£534,000*
Total	**£14,457,000**	*£17,349,000*	*£11,566,000*
Capitalised Natural Capital Value		*High*	*Low*
Fine particles (PM2.5)	**£259,547,000**	*£329,421,000*	*£207,638,000*
Sulfur dioxide (SO2)	**£344,000**	*£437,000*	*£276,000*
Nitrogen dioxide (NO2)	**£30,120,000**	*£38,228,000*	*£24,096,000*
Ozone (O3)	**£14,028,000**	*£17,805,000*	*£11,222,000*
Total	**£304,039,000**	*£385,891,000*	*£243,231,000*

Present value, 2018 prices; capitalised central value discounted at 1.5% over 25 years (quality of life benefits).

Source: ***Author calculation based on Jones et al. (2017) and*** (ONS, 2018c).

2.4 Recreation

The cultural ecosystem service 'recreation' is part of general leisure, and is not always easily distinguished from other ecosystem services such as education or aesthetic values. It usually

refers to doing things and interacting with others.[21] Natural capital assets such as parks provide the setting for a wide range of human activities including walking, running, cycling, climbing and horse riding. It also provides space for picnicking or observing nature, including bird watching, and for informal relaxation. Recreational activities raise individual wellbeing and are therefore a value in itself.[22] But there are also links between recreation and health benefits (see Section 2.5).

To calculate the recreational value provided by natural capital assets managed by Birmingham City Council, the Outdoor Recreation Valuation (ORVal) toolkit version 2.0 (Day and Smith, 2018a) was used. ORVal is a tool to assess the welfare value of outdoor recreation developed by the University of Exeter. ORVal's estimations are derived from a statistical model of recreational demand by people over 16 years of age. The model provides estimates of peoples' recreational behaviour, based on their particular characteristics and location. The model is designed to predict how many visits to greenspace are likely to be undertaken by each individual and how much welfare value they get from each visit (Day and Smith, 2018b).

The ORVal model was informed by Natural England's Monitor of Engagement with the Natural Environment (MENE) survey data. The welfare value calculation is based on the travel cost method:

> *"…the welfare derived from visiting a particular greenspace is modelled as a trade-off between the benefits of enjoying time at that site and the costs incurred in getting there. …the costs of getting to the site are calculated as the sum of a 25p per km travel cost (based on estimates of the average variable costs of car travel) and the costs of travel time (based on Department for Transport estimates)."*
> (Day and Smith, 2018b, p. 5)

ORVal was applied for the geographic scope of Birmingham. The types of designations applied to best match the study scope include country parks, nature, parks, path and woodland. No other filters were applied. Based on these specifications, ORVal modelled 35.2 million annual visits to greenspace in Birmingham with a welfare value of £108.2 million each year. The average welfare value per visit was modelled as £3.07. This reflects the opportunity (travel) costs incurred for visiting a site. It is important to note that these figures are not based on actually observed visits but rather the modelled visit prediction (Day and Smith, 2018b).

To test the model predictions, we also calculated the estimated visits to greenspaces in Birmingham using the MENE results for the period 2009/10 to 2015/16 applying similar

[21] (Church et al., 2011)
[22] (See e.g. UK NEA, 2011a)

parameters. This analysis resulted in an estimated annual visitor count of 32.5 million which is fairly close to the ORVal model prediction of 35.2 million visits. To calculate the monetary value of recreation for the purpose of these natural capital accounts, values were based on the more conservative estimate of MENE-based observed visitor counts rather than the ORVal-modelled ones.

To estimate the number of visits to greenspace managed by Birmingham City Council rather than greenspace within the geographical area of Birmingham as above, we divided the total number of visits by the area of accessible greenspace (public and private open space/playing fields as a proxy) within Birmingham and multiplied the result by the area of greenspace managed by Birmingham City Council (public open space/playing fields as a proxy) in addition to Council-managed greenspace outside the Birmingham boundary which is assumed to be accessible. The estimated annual number of visits to Council-managed greenspace is 31.5 million. Applying the average WTP of £3.07 as modelled by ORVal results in a welfare value of £96.7 million annually or £1.7 billion capitalised.

Figure 2.7 Recreation Benefits

Physical Accounts

		Annually	Over 25 years
Estimated number of visits to Natural Capital		31,488,906	787,222,644
…of which by socio-economic group: AB		7,654,368	191,359,209
…of which by socio-economic group: C1		9,947,088	248,677,195
…of which by socio-economic group: C2		5,861,287	146,532,165
…of which by socio-economic group: DE		8,026,163	200,654,075
…of which by car as transport mode		13,183,756	329,593,908
…of which by other transport mode		18,305,149	457,628,735

Monetary Accounts

Annual Natural Capital Value		*High*	*Low*
Recreation	**£96,739,000**	*£100,005,000*	*£93,473,000*
Capitalised Natural Capital Value		*High*	*Low*
Recreation	**£1,650,209,000**	*£1,793,643,000*	*£1,594,497,000*

Present value, 2018 prices; capitalised central value discounted at 3.5% over 25 years; High/Low : Sensitivity analysis.

Source: ***Author calculation based on Day and Smith (2018a).***

ORVal also predicts the visitor numbers for different socio-economic groups and transport modes. These predictions have been adjusted in a similar way as the total visitor counts and are summarised in Figure 2.2. The range of the sensitivity analysis is based on the margin of error of the MENE results.[23]

Please note that these figures represent an underestimation because the welfare value of children under 16 years of age is not included in the assessment. It should also be stressed that values are based on summed marginal values (of losing one/few sites) rather than the absolute value (of losing all sites together). The ORVal model assumes that, if a particular

[23] Based on the Rule of Thumb

greenspace would not exist anymore, people could still access other substitutional greenspaces nearby which reduces the welfare loss. Hence, the stated values represent the added-up welfare value provided by each individual greenspace, assuming that all other sites remain as possible substitutes. If all Council-managed greenspace would disappear, the welfare loss would be much greater than the capitalised £1.7 billion. Please also note that overlaps with other calculated benefits are likely. That is why the figures presented here in Figure 2.7 have been adjusted for aggregation (see Section 2.10).

2.5 Global climate Regulation

Since the pre-industrial era, Global Greenhouse Gas (GHG) emissions due to human activity have increased to a level unprecedented in at least the last 800,000 years. These anthropocentric GHG emissions are "extremely likely" to be the dominant cause for the observed global warming since the mid-20th century (IPCC, 2014).

> *"…the [Stern] Review estimates that if we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more."* (Stern, 2006, p. vi)

Natural capital plays an important role in mitigating climate change and its negative impacts by sequestering and storing carbon. The photosynthetic activities of trees and other plants sequester carbon dioxide (CO_2) from the atmosphere and store it as carbon in vegetation and soils; therefore acting as a net carbon sink (Read et al., 2009).

One of the main carbon sinks is woodland. The Forestry Commission estimates that an increased UK woodland stock could contribute an emission abatement equivalent to 10% of the total UK greenhouse gas inventory in 2050. This could be achieved by replanting an additional 4% of the UK land cover with woodland (Read et al., 2009).

Woodland in Great Britain has an average carbon stock of 308 tonnes per hectare (tC/ha) equivalent to about 1,131 tonnes of CO_2/ha. 76% of carbon is stored on woodland soils (assessed here down to 1m depth) rather than in trees and litter/deadwood (Morison et al., 2012). When applying the average carbon stock to woodland managed by Birmingham City Council, a total carbon stock in Council-managed woodland of 353,129 tC (1,296,719 tCO_2) can be estimated. The assumption underlies that the species composition, tree size and

management etc. of woodland in Birmingham is comparable to woodland in Great Britain as a whole.

To estimate the carbon stock for other natural capital features, the estimates provided in Alonso et al. (2012) were used. The average carbon stock in assessed vegetation and soils (only assessed to 15cm depth) ranges from 60 tC/ha (220 tCO_2/ha) for modified grassland to 90 tC/ha (330 tCO2/ha) for heathland.[24] The total carbon stock in Council-managed non-woodland habitats and corresponding soils is in the region of 208,925 tC (766,060 tCO_2). See Figure 2.4 for a breakdown.

To calculate the monetary value of the carbon stock in Council-managed natural capital assets, the estimated total 562,055 tC (2,062,779 tCO_2) stored in Council-managed natural capital has been multiplied by the price for non-traded carbon recommended by the Department of Business, Energy & Industrial Strategy (BEIS, 2019). For this assessment, the average central carbon price over our assessment period of 25 years has been applied. This results in a total stock value for carbon stored in Council-managed natural capital assets of £221 million. For the sensitivity analysis, a range of 50% has been applied in line with the range recommended by the BEIS (2019).

As this is a stock value rather than a capitalised service flow value, an annual value cannot easily be derived. To make the value comparable with other annual figures in this report, the stock value has been annualised. For this purpose, the stock value has been annualised over the assessment period of 25 years applying a discount rate of 3.5%. This results in an annualised stock value of £13 million. This approach seems justifiable to ensure consistency across the accounts and given that the overall proportion of global climate regulation in relation to the total natural capital value is rather marginal. Please note that this figure does not represent the value of annually sequestered carbon. It is rather the value of carbon stored, divided by 25 years (applying a discount rate of 3.5%).

Figure 2.8 Global Climate Regulation Benefits

[24] Please note that the average carbon stock for heathland has also been applied to hedgerows for which no separate estimates were stated in Alonso et al., 2012. This is assumed to be a conservative estimate.

Physical Accounts			
		tonnes carbon (tC)	tonnes CO2 (tCO2)
Total estimated woodland carbon stock		353,129	1,296,719
…of which is standing trees		65,256	239,624
…of which is litter & deadwood		19,670	72,231
…of which is woodland soil carbon (to 1 meter depth)		268,204	984,864
Total estimated non-woodland carbon stock		219,966	806,544
…of which is acid grassland		5,570	20,423
…of which is neutral grassland		28,803	105,609
…of which is modified (amenity/improved) grassland		124,410	456,170
…of which is heathland		38,543	141,325
…of which is hedgerows		2,268	8,315
…of which is fen, marsh & swamp		9,332	34,217
…of which is arable & horticulture		11,041	40,483
Total estimated carbon stock		573,096	2,103,262
Monetary Accounts			
Annualised Stock Value		*High*	*Low*
Woodland Carbon Stock	**£7,989,000**	*£11,984,000*	*£3,995,000*
Non-Woodland Carbon Stock	**£4,969,000**	*£7,454,000*	*£2,485,000*
Total	**£12,959,000**	*£19,438,000*	*£6,479,000*
Natural Capital Stock Value		*High*	*Low*
Woodland Carbon Stock	**£136,286,000**	*£214,942,000*	*£68,143,000*
Non-Woodland Carbon Stock	**£84,769,000**	*£133,691,000*	*£42,384,000*
Total	**£221,055,000**	*£569,688,000*	*£110,527,000*
Stock value, 2018 prices; annualised central value discounted at 3.5% over 25 years; High/Low: Sensitivity analysis.			

Source: ***Author calculation.***

Considering that this assessment does not cover non-woodland soils below 15 cm depth or account for Council-managed street and highway trees, this figure is likely to be underestimating the real carbon value stored in Council-managed natural capital.

2.6 Food Production from Allotments

Whilst the extent of allotment space in England has declined by an estimated 90% since the second world war, more recently demand has increased significantly again, especially in inner cities.

> *"Factors such as an increased interest in organic food, concerns over reliance on importations, desire for a greater sense of self-sufficiency […], concerns over food costs, and general worries about food security are driving the increasing pressure on limited allotment space."* (Davies et al., 2011, p. 376)

Whilst food production is the most obvious ecosystem service provided by allotments, the recreational value and attached health benefits associated with using allotments and gardening more generally may be much higher. A non-systematic literature review for example suggests that gardening in an allotment setting may have a range of positive physical and mental health impacts (Garden Organic and Sustain, 2014). However, within

scope of this assessment we limit our focus on the food production value from allotments. Further research is required on other impacts of allotment use to assess wider wellbeing benefits.

Because food produced in UK allotments cannot be sold, statistics on allotment food production and value is scarce. However, Eftec (2017) used available data to estimate the food production value from allotments in the UK as part of a scoping study to inform national urban natural capital accounts. Here, we adopt a similar approach to estimate the food produced in Birmingham City Council-managed allotments.

Birmingham City Council manages 7333 allotment plots. The total area of Council-managed allotments is 259 ha[25]. Allotment plot sizes in Birmingham vary from Mini (up to 84 m^2) to Large (335-502 m^2). We assume that the average plot size is 250 m^2 which is a standard plot size in the UK (Eftec, 2017). This seems plausible given that the average total allotment space including common infrastructure such as connection roads is about 350 m^2 per plot (total allotment area of 259 ha divided by 7333 plots).

The occupancy level of Council-managed allotment plots is about 81% which means that, on average, about 5,940 plots are in active use. A literature review by Eftec (2017) concluded that the most reliable food production estimate per standard 250 m^2 allotment plot is 487 kg per year. This figure, which is based on an Royal Horticultural Society study in 1975 has been considered to be *"the only known statistical record of vegetable crop produce harvested from allotment plots"* (Cook, 2006, p. 93). Multiplying the number of occupied allotment plots (5,940) by the estimated food produce per plot (487 kg) results in an estimated annual food produce in Council-managed allotments of 2,900 tonnes.

To estimate the monetary value of this food produce, we used the estimated value per allotment plot of £731 (adjusted to 2018-prices and a standard plot size of 250 m^2) based on Cook (2006). The same value was also used to inform national urban natural capital accounts (Eftec, 2017). When multiplying the value per plot (£731) by the number of occupied plots in Birmingham (5,940), we arrive at an estimated annual value of £4.3 million for food produced in Council-managed allotments. This represents a value of about £1.50 per kg of produced food. The capitalised value over an assessment period of 25 years is in the region of £74 million.

The literature review by Eftec (2017) suggests that annual allotment produce from a standard 250 m2 plot ranges from £572 to £2,441 (adjusted to 2018-prices). This range has been adopted to inform the sensitivity analysis. All figures are summarised in Figure 2.9.

Figure 2.9 Food Production from Allotments

[25] Birmingham City Council data for the first half of 2019.

Physical Accounts			
Total number of allotment plots			7,333
Estimated number of allotment plots in productive use			5,940
		Annually	Over 25 years
Estimated food production in kg		2,893,000	72,316,000
Monetary Accounts			
Annual Natural Capital Value		*High*	*Low*
Allotment food production	**£4,341,000**	*£14,497,000*	*£3,396,000*
Capitalised Natural Capital Value		*High*	*Low*
Allotment food production	**£74,055,000**	*£260,008,000*	*£57,922,000*
Present value, 2018 prices; capitalised central value discounted at 3.5% over 25 years; High/Low : Sensitivity analysis.			

Source: ***Author calculation.***

2.7 Biodiversity (Non-use Benefits Only)

The term 'biodiversity' generally describes the diversity of life on earth, both between and within species. Biodiversity has three main functions concerning ecosystem services and natural capital (UK NEA, 2011a):

1. Ecosystem processes: Biodiversity may play a role in the dynamics of ecosystem services, for example, in nutrient cycling.

2. Genes and species: Some species and genetic variability within them contribute directly to goods and benefits. For example, the diversity of wild crop is important for the improvement of crops and livestock. Resistance to diseases also increases with genetic diversity.

3. Valued by people: The appreciation of wildlife and places and the spiritual, educational, religious and recreational values are direct benefits that result from biodiversity.

It is important to stress that biodiversity underpins all ecosystem services as all, at least partially, depend on living organisms and processes:

> *"All ecological processes are the product of interactions between different groups of organisms and are dependent on there being a range of these present. In this sense, biodiversity – the variety and variability of living organisms – ultimately underpins the functioning of all ecosystems and thereby the delivery of all ecosystem services."* (UK NEA, 2011b, p. 19)

Hence, the value of biodiversity is partially implicit in all natural capital assets assessed within the scope of this investigation.

Within the section, we focus on the non-use values of biodiversity which can be seen as an ecosystem service in itself (in addition to all other aspects of the total value of biodiversity implicit in all other ecosystem services). Non-use values refer to human preferences for protecting and enhancing biodiversity without directly experiencing it such as through wildlife watching. People have a preference for the pure existence of biodiversity and species where people benefit from simply knowing it is there as well as bequest values where people benefit from knowing that future generations will be able to benefit from biodiversity (Morling et al., 2010).

To quantify the monetary biodiversity value of woodland in Birmingham, the findings provided by Hanley et al. (2002) were used for a benefit transfer. The biodiversity value of other habitats is calculated further below. Hanley et al. (2002) value the existence (non-use) benefits of woodland as habitat for species. They valued the WTP for woodland habitats with different attributes, expressed by focus groups. This study was also applied to quantify the social and environmental benefits provided by woodland in Great Britain as a whole (Willis et al., 2003).

The mean WTP to create or protect areas of certain woodland types (including Ancient Semi-Natural Woodland; ASNW) were calculated on a per-household basis in Hanley et al. (2002). These values have been re-calculated to per-ha values and adjusted to 2017 prices. Because this is a non-use value, the benefits are basically not restricted to local residents.

> *"There is no reason within standard economic theory why non-use values would also decrease with distance."* (Brander et al., 2008, p. 18)

However, revealing human preferences for non-use values is challenging because of their inchoate nature (Morling et al., 2010) and could well include use-values as well. To account for such uncertainties, the lower range of the sensitivity analysis in this assessment has been calculated based on the assumption that only residents in the West Midlands region benefit from woodland biodiversity in Birmingham. For the upper range of the sensitivity analysis, the assumption applies that all UK residents benefit from woodland biodiversity in Birmingham. The central estimate is calculated as the mean between the upper and lower range of the sensitivity analysis. The non-use biodiversity value (central estimate) provided by Council-managed woodland was estimated to be in the order of £1.7 million annually or £28.4 million capitalised.

To calculate the biodiversity benefits provided by other habitats in Birmingham, the findings provided by Christie et al. (2011) were used for a benefit transfer. Specific objectives of that primary valuation study were to assess the marginal value of ecosystem services per habitat associated with the UK Biodiversity Action Plan (UK BAP) and the marginal value of conservation activities associated with different scenarios.

The data has been used to re-calculate the biodiversity value per ha rather than the value change due to a change in management. The assumption underlies that the per-ha values across the UK are representative for per-ha values in Birmingham as well. Values were adjusted to 2018 prices.

Christie et al. (2011) calculated values for the biodiversity benefits 'within own region' (where respondents live) and outside own region (aggregated for all other UK regions). Whilst a clear definition of what constitutes the 'habitat for species' value (e.g. use or non-use value) is lacking in Christie et al. (2011), the distinction between 'within and outside own region' allowed us to make some assumptions.

For the upper threshold of the sensitivity analysis, we assume that all values (within and outside own region) represent non-use values. For the lower threshold of the sensitivity analysis, we only apply the 'outside own region' values assuming that values 'inside own region' are mainly use values. For the central estimate, we assume that the benefits 'within own region' is partially based on non-use values which is also indicated by the difference between 'within' and 'outside' values. In absence of alternatives, we assume that 50% of the biodiversity value 'within own region' can be attributed to non-use values. The central estimate is therefore the value 'outside own region' plus half of the value 'within own region'.

The total non-use biodiversity value (including woodland above) was estimated to be in the order of £2.3 million annually or £38.9 million capitalised. Detailed findings including sensitivity analysis are summarised in Figure 2.10.

Figure 2.10 Non-use Biodiversity Value

Physical Accounts			
			Assessed area in ha
Grassland			2,609
Woodland & dense scrub			1,147
Heathland			428
Hedgerows			25
Wetland			123
Arable			0
Monetary Accounts			
Annual Natural Capital Value		*High*	*Low*
Grassland	**£343,000**	*£480,000*	*£206,000*
Woodland & dense scrub	**£1,662,000**	*£3,063,000*	*£261,000*
Heathland	**£215,000**	*£297,000*	*£133,000*
Hedgerows	**£9,000**	*£13,000*	*£6,000*
Wetland	**£50,000**	*£69,000*	*£31,000*
Arable	**£0**	*£0*	*£0*
Total	**£2,280,000**	*£3,922,000*	*£637,000*
Capitalised Natural Capital Value		*High*	*Low*
Grassland	**£5,852,000**	*£8,613,000*	*£3,513,000*
Woodland & dense scrub	**£28,353,000**	*£54,944,000*	*£4,448,000*
Heathland	**£3,673,000**	*£5,331,000*	*£2,274,000*
Hedgerows	**£160,000**	*£231,000*	*£101,000*
Wetland	**£849,000**	*£1,229,000*	*£529,000*
Arable	**£0**	*£0*	*£0*
Total	**£38,886,000**	*£70,348,000*	*£10,865,000*
Present value, 2018 prices; capitalised central value discounted at 3.5% over 25 years; High/Low : Sensitivity analysis.			

Source: ***Author calculation based on Hanley et al. (2002) and Christie et al. (2011).***

Because these are non-use values, people may have problems expressing their own preferences. On the one hand, the topic is very abstract and hard to grasp. On the other, the WTP for this form of ecosystem service is a very small fraction of income which leads to a comparatively wide variation of expressed values. Furthermore, the form of moderation of focus groups and the information provided about the habitats can have a strong influence on the expressed WTP. Hence, calculations for non-use values should generally be treated with some care.

2.8 Flood Risk Regulation

In the UK, soil cover has changed significantly due to human activity, especially within the past 50 years (Smith et al., 2011). The increase in surface sealing has increased soil erosion as well as reducing the capacity of natural vegetation to retain and store water. This applies to urban environments due to the construction of impermeable surfaces such as roads:

> *"The replacement of natural green spaces with concrete and impermeable pavements in urban areas reduces the effectiveness with which rainfall, snow melt and storm water are absorbed and returned to groundwater aquifers. […]*

> *This results in elevated levels of surface water run-off, which increases the likelihood of local flooding and sewers reaching overcapacity."*
> (European Commission, 2012)

But it also applies to rural areas due to soil compaction from heavy agricultural machinery and other land-management changes reducing the extent of vegetation with high infiltration capacities.

The total costs to UK insurers of the 2007 flooding were estimated to be in the order of £3 billion (Pitt, 2007). If no additional flood risk management action is taken, the costs caused by urban flooding alone in the UK could increase to between £1 billion and £10 billion annually under the changing climate. Some scenarios are predicting annual costs arising from UK flooding of £20 billion by 2060 (UK NEA, 2011b).

The risk of flooding to urban and rural areas is not a new concern, but the increase in use of impermeable surfaces, rural land-use changes, population rise and more extreme weather events due to climate change is increasing the frequency and intensity of flooding events as well as the number of properties and value of infrastructure at risk. Natural capital can help to mitigate extreme weather events, and in particular the risk of flooding. Wetland and floodplain habitats fill rapidly during flooding events, at least to a point of saturation, and then slowly filter back retained water to buffer surface flows.

Smithers et al. (2016) quantified flood risk regulation services provided by woodlands for Great Britain at a catchment basis to inform ONS UK Natural Capital Accounts. Based on replacement costs they quantify the asset value at between £1.8 billion and £2.2 billion. However, due to the methods used for this assessment the results were not suitable for a benefit transfer to the Birmingham context.

To calculate the value of flood risk regulation services, the findings from Christie et al. (2011)[26] were used for a benefit transfer (see also Section 3.1). A direct correlation between the area of habitat and the provision of flood risk regulating services has been assumed. For the purpose of this calculation, the WTP 'within own region' and 'outside own region' (Christie et al., 2011) has been applied as also remote areas could benefit for example when water levels of downstream rivers are reduced. Flood risk regulation values were available for a range of natural capital asset types[27] (see Figure 2.3). The annual flood risk regulation value of Council-managed natural capital assets is estimated to be in the order of £1.4 million (£25.1 million capitalised). Since the projected future increase in number and magnitude of flooding events caused by climate change has not been taken into account, the calculated capitalised value is likely to be an underestimation of the real value.

[26] In Christie et al. (2011) flood risk regulation has been phrased water regulation.
[27] It should be noted that the value for lowland meadows has also been applied to other neutral grassland habitats as these are likely to perform similarly in terms of flood risk regulation benefits.

It should be stressed, however, that this is a rather rough estimate because flood risk regulation services are very context-specific and the figures shown here are not based on the specific context of Birmingham rather than a UK average for different habitat types. To acknowledge uncertainties and context-specific variations, a range of 50% was applied for the sensitivity analysis. A similar range has also been applied in Smithers et al. (2016).

In contrast to the USA, applied research into the role of trees and vegetation in water management is relatively scarce in the UK and Europe, despite government strategies such as 'making space for water' (Defra, 2005). This represents a major research gap in the UK because hydrological studies are very site-specific (Saraev, 2012).

Figure 2.11 Flood Risk Regulation Benefits

Physical Accounts

	Assessed area in ha
Grassland	2,609
Woodland & dense scrub	1,079
Heathland	428
Hedgerows	25
Wetland	123

Monetary Accounts

Annual Natural Capital Value		*High*	*Low*
Grassland	**£613,000**	*£919,000*	*£306,000*
Woodland & dense scrub	**£608,000**	*£913,000*	*£304,000*
Heathland	**£162,000**	*£243,000*	*£81,000*
Hedgerows	**£5,000**	*£8,000*	*£3,000*
Wetland	**£83,000**	*£124,000*	*£41,000*
Total	**£1,472,000**	*£2,208,000*	*£736,000*

Capitalised Natural Capital Value		*High*	*Low*
Grassland	**£10,455,000**	*£16,490,000*	*£5,228,000*
Woodland & dense scrub	**£10,378,000**	*£16,368,000*	*£5,189,000*
Heathland	**£2,765,000**	*£4,362,000*	*£1,383,000*
Hedgerows	**£89,000**	*£141,000*	*£45,000*
Wetland	**£1,416,000**	*£2,233,000*	*£708,000*
Total	**£25,104,000**	*£39,593,000*	*£12,552,000*

Present value, 2018 prices; capitalised central value discounted at 3.5% over 25 years; High/Low : Sensitivity analysis.

Source: ***Author calculation based on Christie et al. (2011)***

2.9 Aggregation of Asset Values

One challenge of natural capital accounting is to avoid double counting. The risk is even higher when quantifying such a wide range of services and benefits as in the present study. The ecosystem interactions as well as the relations between different services and benefits are characterised by high complexity. Therefore, particular attention has been paid to this issue.

The property price uplift valuation presents a particular challenge when aggregating monetary values and benefits because the property price uplift value represents a whole bundle of services:

> *"It is not possible presently to disentangle why nature near property is important to the buyer, for example it could be it is aesthetically pleasing or for recreational purposes, the services it provides in clean air and protection from noise pollution could also be factored in. Currently, estimates are considered a bundle of ecosystem services also it is expected that these will be mainly cultural."*
> (ONS, 2018a)

Therefore, particular attention has been paid to ONS's Hedonic Pricing Method (HPM) methodology note which outlines potential overlaps between property price uplifts on the one hand and ecosystem services and other natural capital benefits on the other (ONS, 2018b). Based on this assessment and other considerations, an indicative value overlap assessment has been conducted which is summarised in Figure 2.12. Potential value overlaps between service/benefit domains have been outlined in more detail below.

Figure 2.12 Indicative Value Overlap Assessment

	Property Value Uplift	Council Tax Uplift	Recreation	Physical Health Benefits	Mental Health Benefits	Air Quality Regulation Health Benefits	Flood Risk Regulation	Food Production from Allotments	Global Climate Regulation	Biodiversity (non-use benefits only)
Property Value Uplift										
Council Tax Uplift										
Recreation										
Physical Health Benefits										
Mental Health Benefits										
Air Quality Regulation Health Benefits										
Flood Risk Regulation										
Food Production from Allotments										
Global Climate Regulation										
Biodiversity (non-use benefits only)										

No or marginal potential overlap
Some potential overlap
Significant potential overlap

Note: This overlap assessment is indicative; applicable only to this assessment and its specific valuation methods. The overlaps do not necessarily apply in other contexts.

Source: ***Author assessment***

Council Tax

Considering that house buyers should factor in higher Council Taxes when buying a more expensive property (due to surrounding greenspace), there should be no overlap between property value uplift and Council Tax uplift. However, we recognise that this effect is a matter of debate and it is also arguable that the Council Tax is merely a benefit transfer from home owners to the Council. As a precautionary measure, we completely deduct the Council Tax uplift value from the property value uplift value to avoid any potential double-counting.

We will re-visit this issue in the future to determine if this indeed represents an overlap or if the Council Tax uplift represents an additional value to the property value uplift.

Recreation

In principle there are potential overlaps between recreational benefits and property value/Council Tax uplift. A home buyer may well consider the surrounding greenspace availability for recreational purposes when buying a property. However, in this case the overlaps are likely to be minimal. This is because our calculation of recreational values is based on the travel cost method (see Section 2.4). Applying the travel cost method means that higher values are attributed to greenspace visits from further away because the travel costs (getting there) are higher. Given that accessing a greenspace that is on the doorstep or within short proximity to a property causes virtually no travel costs, we assume that the overlap between recreation and property value/Council Tax Uplift are marginal and do not require a correction.

It is however arguable that recreational values overlap with physical and mental health benefits. Most people deciding to participate in outdoor recreational activities may not primarily do this to improve their health, but for a proportion this may be the main incentive. Hence, overlaps are plausible. In absence of alternatives, we assume that 1/3 (33%) of the mental health benefit as well as physical health benefits are implicit in the recreational value. We acknowledge that this estimate is somewhat arbitrary which means that results should be treated with some care. However, we believe it is closer to the real overlap proportion than assuming a full (100%) overlap or no (0%) overlap. This is an area that requires further research.

Physical Health

Physical health is a benefit of recreational activities which makes overlaps with the property price uplift[28] plausible because people may well think about their health benefits attached to having greenspace close to where they live. To identify the overlap (and double-counting) potential with property value uplift (and Council Tax uplift), we further analysed the MENE statistics used for calculating the physical health benefit value (see Section 2.3.1). We assume that only health benefits related to visiting local greenspaces are potentially considered when buying a property. Using MENE, we therefore analysed the proportion of visitors that access greenspaces within 1 mile from home. The 1 mile threshold is the shortest distance reported in MENE and used as a proxy. The analysis revealed that about 47% of 'active visits by active people' are within 1 mile from home. This proportion represents the potential overlap with property value uplift.

It is not known, however, which proportion of local (within 1 mile) recreational visits is meant for improving physical health rather than for other purposes such as just a fun time outdoors. It is very unlikely that house buyers fully consider the physical health benefit of

[28] Overlaps with recreation have already been factored in above.

having accessible greenspace within a short distance from home. Also, the 1 mile threshold is rather wide. A 1 mile radius is much wider than the 200m threshold used for the ONS (2018b) based property value uplift calculation. Furthermore, the average ward size in Birmingham (669.5 ha) is lower than a 1 mile radius around a property (813.6 ha). Therefore, the applied deduction (47% of physical health benefit value being deducted from property value uplift) is likely to be an overestimate. This means that the overall aggregated value is likely to be an underestimate of the true Council-managed natural capital value. Further research and data is required to refine the assessment.

Mental Health

Mental health benefits are likely to overlap with both, property price uplift and recreation. It is uncertain, however, to which extent. It is plausible that, for most people, mental health considerations due to surrounding greenspace do not play a major role when deciding to visit a park or buying a property. Hence, some potential overlap has been assumed. In absence of alternatives, we assume that 1/3 (33%) of the mental health benefit is implicit in the property value uplift and recreational value, respectively. We acknowledge that this estimate is somewhat arbitrary. But given that the overall impact on the total results is rather marginal we think this is justifiable. Due to the quantification methods applied, there should be no overlap between mental and physical health benefits.

Air Quality Regulation

Local air quality is likely to play a role when buying a property. But considering that local natural capital only has a limited effect on overall air quality in an area (which is more likely to be part of the consideration when buying a property) the overlap is probably marginal. Hence, no correction has been applied.

Flood Risk

Local flood risk could well be a factor when buying a property. But because flood risk is based on many factors and not just on the local availability of greenspace, the overall effect of (local natural) flood risk regulation services on property values is likely to be rather small. In absence of alternatives, we assume that 1/3 (33%) of the flood risk regulation value is implicit in the property value uplift. As for mental health benefits, we acknowledge that this estimate is somewhat arbitrary. But given that the overall impact on the total results is rather marginal we think this is justifiable.

The benefit from global climate regulation is independent from where the service is provided. It does not matter for climate change if a tonne of carbon is stored in Birmingham or for example in Brazil. Hence, no overlaps should occur with other services and benefits. A similar assumption applies for biodiversity because only non-use values are assessed. Therefore, no overlaps are assumed. There should also be no overlaps assumed between flood production from allotments and other services.

Below we outline in Table 2.1 and Table 2.2 which potential overlaps occur between property value uplift, recreation, and other services and benefits. Further corrections to the Council Tax uplift are not required because the full Council Tax uplift value is already assumed to be implicit in the property value uplift. There are no further double-counting issues with Council Tax uplift (see aggregated results; Table 4.1).

Table 2.1 Potential Overlap Correction: Property Value Uplift

Asset & corrections	Total asset value	Estimated magnitude of potential overlap	Deducted value (to avoid overlaps)	Asset value after deductions	Remaining asset value in %	Notes
Property value uplift	£7.18			£7.18		This is the property value uplift value before corrections (deductions)
Corrections (deductions to mitigate potential double-counting)						
Council Tax uplift	£0.48	100%	-£0.48	£6.70	93%	Council Tax uplift is completely deducted as precautionary measure
Physical health benefits	£4.06	47%	-£1.89	£4.81	67%	The deduction is based on the estimated proportion of visits within 1 mile from home. Other visits are from outside the local area around the visitor's property which means overlaps with property value uplift are unlikely.
Mental Health	£0.20	33%	-£0.07	£4.74	66%	Some potential overlap is possible. In absence of alternatives we assume that the overlap is in the magnitude of 33%.
Flood Risk Regulation	£0.03	33%	-£0.01	£4.75	66%	Some potential overlap is possible. In absence of alternatives we assume that the overlap is in the magnitude of 33%.
Total property value uplift after corrections				**£4.75**	**66%**	This is likely to indicate mainly the amenity value contained within the property value uplift
Note: All values are stated in £ billions; 2018 prices.						

Source: ***Author calculation***

Table 2.2 Potential Overlap Correction: Recreation

Asset & corrections	Total asset value	Estimated magnitude of potential overlap	Deducted value (to avoid overlaps)	Asset value after deductions	Remaining asset value in %	Notes
Recreation	£1.65			£1.65		This is the recreational value before corrections (deductions)
Corrections (deductions to mitigate potential double-counting)						
Physical health benefits	£1.65	33%	-£0.55	£1.10	67%	It is arguable that some recreational activities are mainly undertaken to benefit from physical health improvements attached to recreational activities. In absence of alternatives we assume that the overlap is in the magnitude of 33%. Here, we use the recreational value as 'total asset value' because the total physical health benefits are higher than the recreational benefits. Effectively, we are deducting the recreational value by 33% rather than the physical health benefit.
Mental health benefits	£0.20	33%	-£0.07	£1.03	63%	It is arguable that some recreational activities are mainly undertaken to benefit from mental health improvements attached to recreational activities. In absence of alternatives we assume that the overlap is in the magnitude of 33%.
				£1.03	**63%**	
Note: All values are stated in £ billions; 2018 prices.						

Source: ***Author calculation***

3. Conventional Parks Accounts

The conventional parks accounts are based on Birmingham's Parks Services Budget for 2018/19. This covers liabilities such as wages and ground maintenance costs as well as direct revenue income such as fees for parking and facilities. After consultations with Birmingham City Council, both, the expenditure and the revenue income has been corrected (reduced) by 9.72 million. The corrected figures better represent the actual parks and greenspaces expenditure and income. An addition to the liabilities has been made for an external Heritage Lottery Funding (HLF) grant over nearly £100,000 per annum which supports greenspace management but is not included in the Parks Services Budget.

The annual expenditure and income was capitalised over 25 years, applying a discount rate of 3.5%. The assumption underlies that costs and benefits will remain unchanged over time.

Figure 3.1 Conventional Parks Accounts

	Annual	Capitalised
Expenditure	£25,567,000	£436,123,000
Revenue Income	-£13,407,000	-£228,708,000
Adjustments	-£462,000	-£7,881,000
Net-Expenditure	**£11,697,000**	**£199,535,000**

Present value, 2018 prices; capitalised central value discounted at 3.5% over 25 years.

Source: ***Author calculation based on data provided by Birmingham City Council***

One can see that, based on conventional accounting methods, Birmingham's park services report a net-expenditure (net-liability). The following Chapter will reveal that this is a narrow and somewhat misleading assessment of Birmingham's parks services' contribution to both, Birmingham's public coffers and society as a whole.

4. Results

The results of the Birmingham Health Economic Assessment & Natural Capital Accounts are summarised in Figure 4.1 for stock and capitalised values over an assessment period of 25 years. Annual and annualised values are presented in Figure 4.2 further below. Please note that some values (property value uplift and recreation) have been adjusted before aggregation to avoid potential double-counting (please refer to Section 2.9 for details).

The assessment shows that Council-managed parks and greenspaces represent a net natural capital asset with an indicative value of £11 billion. The annual net-value is in the order of £594 million. The Benefit-Cost Ratio (BCR) is 26.2 : 1 which means that every £1 spend on Council-managed parks and greenspaces returns £26.20 to society.[29]

Figure 4.1 Natural Capital Balance Sheet: Stock/Capitalised Values over 25 Years

Capitalised/stock values stated in £billions; 2018 prices; central estimates		Individual value	Adjustment: Applied % of individual value to avoid double-counting	Adjusted values for aggregation (to avoid double-counting) Total Natural Capital Value	Health Benefits	Direct & Indirect Council Income	Conventional Accounts
Assets							
Property value uplift	S	£7.18	66%	£4.75			
Council Tax uplift	F	£0.48	100%	£0.48		£0.48	
Physical health benefits	F	£4.06	100%	£4.06	£4.06		
Mental health benefits	F	£0.20	100%	£0.20	£0.20		
Air quality regulation	F	£0.30	100%	£0.30	£0.30		
Recreation	F	£1.65	63%	£1.03			
Global climate regulation	S	£0.22	100%	£0.22			
Food production from allotments	F	£0.07	100%	£0.07			
Biodiversity (non-use benefits only)	F	£0.04	100%	£0.04			
Flood risk regulation	F	£0.03	100%	£0.03			
Direct parks income	F	£0.23	100%	£0.23		£0.23	£0.23
Adjustments	F	-£0.01	100%	-£0.01		-£0.01	-£0.01
Gross asset value				**£11.41**	**£4.56**	**£0.70**	**£0.22**
Liabilities							
Parks services expenditure		£0.44	100%	£0.44	£0.44	£0.44	£0.44
Net-Value				**£10.97** to society	**£4.13** in health benefits	**£0.27** to the Council	**-£0.22** as per books
Benefits-Cost Ratio				***26.2 : 1***	***10.5 : 1***	***1.6 : 1***	***0.5 : 1***

Notes:
S Based on stock value
F Based on capitalised flow value (present value; discounted over 25 years)

Source: ***Author calculation***

[29] Based on capitalised values. The BCR's of /capitalised values (Figure 4.1) and annual values (Figure 4.2) differ because different discount rates were applied. A higher discount rate of 3.5% has been applied for all liabilities whilst some of the assets (health-related) have been discounted at a reduced rate of 1.5%. See Section 2.4.

It is important to stress that the stated biodiversity value of about £40 million only represents a small fraction of the overall biodiversity value. All benefits and services are at least partially dependent on biodiversity which means that they all have a certain biodiversity value implicit.

The net asset value of health benefits is nearly £4 billion which for example relates to 83,000 added Quality Adjusted Life Years (QALYs) over a time period of 25 years. The annual net health benefit of Council-managed parks and greenspaces is in the order of £182 million.

From a Birmingham City Council finance perspective only, Council-managed parks and greenspaces still provide a net-return of £270 million when also accounting for the Council Tax uplift. For every £1 the Council spends on its Parks Services, it gains a return of £1.60 in Council Tax and direct parks income. The only accounts that report Birmingham's parks and greenspaces as a net-liability are Birmingham's conventional accounts (-£13 million annually; -£220 million capitalised over 25 years) which highlights the limitations of conventional accounting when public goods such as parks are affected.

Figure 4.2 Natural Capital Balance Sheet: Annual(ised) Flow Values

Annual(ised) values stated in £millions; 2018 prices; central estimates		Individual value	Adjustment: Applied % of individual value to avoid double-counting	Adjusted values for aggregation (to avoid double-counting)			
				Total Natural Capital Value	**Health Benefits**	**Direct & Indirect Council Income**	**Conventional Accounts**
Assets							
Property value uplift	S	£421	66%	£279			
Council Tax uplift	F	£28	100%	£28		£28	
Physical health benefits	F	£193	100%	£193	£193		
Mental health benefits	F	£10	100%	£10	£10		
Air quality regulation	F	£14	100%	£14	£14		
Recreation	F	£97	63%	£61			
Global climate regulation	S	£13	100%	£13			
Food production from allotments	F	£4	100%	£4			
Biodiversity (non-use benefits only)	F	£2	100%	£2			
Flood risk regulation	F	£1	100%	£1			
Direct parks income	F	£13	100%	£13		£13	£13
Adjustments	F	£0	100%	£0		£0	£0
Annual service/benefit value				**£619**	**£218**	**£41**	**£13**
Liabilities							
Parks services expenditure		£26	100%	£26	£26	£26	£26
Annual net-value				**£594** to society	**£192** in health benefits	**£16** to the Council	**-£13** as per books
Benefits-Cost Ratio				***24.2 : 1***	***8.5 : 1***	***1.6 : 1***	***0.5 : 1***

Notes:
S Based on annualised stock value
F Based on annual flow value

Source: ***Author calculation***

The annual accounts (Figure 4.2) include annualised stock values (marked with an 'S'). Here, stock values were annualised over the assessment period of 25 years applying an appropriate discount rate.

To estimate the natural capital value per Birmingham resident (Figure 4.3 for stock/capitalised values and Figure 4.4 annual/annualised values, respectively), values were simply divided by the estimated number of residents in Birmingham. This is a rough indication because natural capital in Birmingham does not only benefit local residents. Visitors to Birmingham benefit for example also from recreational benefits and global climate regulation benefits, as the name indicates, people all over the world as it does not matter where a tonne of carbon is stored.

The indicative annual net asset value provided by Birmingham City Council managed parks and greenspaces per resident is £520. If capitalised over an assessment period of 25 years, this results in a net asset value of just over £9,600.

Figure 4.3 Indicative Stock/Capitalised Values over 25 Years per Resident

Capitalised/stock values stated in £; 2018 prices; central estimates		Individual value	Adjustment: Applied % of individual value to avoid double-counting	Adjusted values for aggregation (to avoid double-counting) Total Natural Capital Value	Health Benefits	Direct & Indirect Council Income	Conventional Accounts
Assets							
Property value uplift	S	£6,294	66%	£4,164			
Council Tax uplift	F	£422	100%	£422		£422	
Physical health benefits	F	£3,555	100%	£3,555	£3,555		
Mental health benefits	F	£176	100%	£176	£176		
Air quality regulation	F	£266	100%	£266	£266		
Recreation	F	£1,446	63%	£905			
Global climate regulation	S	£194	100%	£194			
Food production from allotments	F	£65	100%	£65			
Biodiversity (non-use benefits only)	F	£34	100%	£34			
Flood risk regulation	F	£22	100%	£22			
Direct parks income	F	£200	100%	£200		£200	£200
Adjustments	F	-£7	100%	-£7		-£7	-£7
Gross asset value				**£9,997**	**£3,997**	**£615**	**£193**
Liabilities							
Parks services expenditure		£382	100%	£382	£382	£382	£382
Net-Value				**£9,614** to society	**£3,615** in health benefits	**£233** to the Council	**-£189** as per books
Benefits-Cost Ratio				***26.2 : 1***	***10.5 : 1***	***1.6 : 1***	***0.5 : 1***

Notes:
S Based on stock value
F Based on capitalised flow value (present value; discounted over 25 years)

Source: ***Author calculation***

Figure 4.4 **Indicative Annual(ised) Values per Resident**

Annual(ised) values stated in £; 2018 prices; central estimates		Individual value	Adjustment: Applied % of individual value to avoid double-counting	Adjusted values for aggregation (to avoid double-counting) Total Natural Capital Value	Health Benefits	Direct & Indirect Council Income	Conventional Accounts
Assets							
Property value uplift	S	£369	66%	£244			
Council Tax uplift	F	£25	100%	£25		£25	
Physical health benefits	F	£169	100%	£169	£169		
Mental health benefits	F	£9	100%	£9	£9		
Air quality regulation	F	£13	100%	£13	£13		
Recreation	F	£85	63%	£53			
Global climate regulation	S	£11	100%	£11			
Food production from allotments	F	£4	100%	£4			
Biodiversity (non-use benefits only)	F	£2	100%	£2			
Flood risk regulation	F	£1	100%	£1			
Direct parks income	F	£12	100%	£12		£12	£12
Adjustments	F	£0	100%	£0		£0	£0
Gross asset value				**£542**	**£191**	**£36**	**£11**
Liabilities							
Parks services expenditure		£22	100%	£22	£22	£22	£22
Net-Value				**£520** to society	**£168** in health benefits	**£14** to the Council	**-£11** as per books
Benefits-Cost Ratio				***24.2 : 1***	***8.5 : 1***	***1.6 : 1***	***0.5 : 1***

Notes:
S Based on annualised stock value
F Based on annual flow value

Source: ***Author calculation***

It should be noted that the scientific basis for the economic valuation of natural capital is imperfect. Therefore, the values should be interpreted as best estimates of the magnitude of the natural capital value rather than the ultimate truth. In fact, the estimates here are still likely to understate the real total natural capital value. This is because some of the assessed ecosystem services and benefits could only be partially valued or not valued at all in monetary terms within the scope of this assessment. This includes for example noise mitigation and educational benefits of interaction with nature. Furthermore, the expected population growth Birmingham faces is likely to increase the demand for and therefore the value of natural capital over time which is not factored in into the calculations.

4.1 Sensitivity Analysis

The sensitivity analysis shows that, even when applying a range to account for uncertainties, the general picture does not change significantly. Even the low estimates in terms of services and benefits still show both, positive net asset values as well as positive BCRs. The only exception is direct and indirect Council income where the lower estimate of the sensitivity analysis indicates a possible net-liability and therefore negative BCR. Please refer to the relevant sections in Chapter 2 for methods, assumptions and caveats concerning the sensitivity analysis.

Figure 4.5 Natural Capital Balance Sheet: Sensitivity Analysis of Stock/Capitalised Values

Capitalised/stock values stated in £billions; 2018 prices	**Total Natural Capital Value**		**Health Benefits**		**Direct & Indirect Council Income**	
	High Estimate	*Low Estimate*	*High Estimate*	*Low Estimate*	*High Estimate*	*Low Estimate*
Assets						
Property value uplift	£9.15	£0.36				
Council Tax uplift	£0.97	£0.04			£0.97	£0.04
Physical health benefits	£5.50	£2.91	£5.50	£2.91		
Mental health benefits	£0.28	£0.14	£0.28	£0.14		
Air quality regulation	£0.39	£0.24	£0.39	£0.24		
Recreation	£1.12	£1.00				
Global climate regulation	£0.57	£0.11				
Food production from allotments	£0.26	£0.06				
Biodiversity (non-use benefits only)	£0.07	£0.01				
Flood risk regulation	£0.04	£0.01				
Direct parks income	£0.23	£0.23			£0.23	£0.23
Adjustments	-£0.01	-£0.01			-£0.01	-£0.01
Gross asset value	£18.57	£5.10	£6.17	£3.29	£1.20	£0.26
Liabilities						
Parks services expenditure	£0.44	£0.44	£0.44	£0.44	£0.44	£0.44
Net-Value	**£18.13** to society	**£4.67** to society	**£5.73** in health benefits	**£2.86** in health benefits	**£0.76** to the Council	**-£0.18** to the Council
Benefits-Cost Ratio	***42.6 : 1***	***11.7 : 1***	***14.1 : 1***	***7.6 : 1***	***2.7 : 1***	***0.6 : 1***

Source: ***Author calculation***

Figure 4.6 Natural Capital Balance Sheet: Sensitivity Analysis of Annual(ised) Values

Annual(ised) values stated in £millions; 2018 prices	Total Natural Capital Value		Health Benefits		Direct & Indirect Council Income	
	High Estimate	*Low Estimate*	*High Estimate*	*Low Estimate*	*High Estimate*	*Low Estimate*
Assets						
Property value uplift	£536	£21				
Council Tax uplift	£54	£2			£54	£2
Physical health benefits	£247	£138	£247	£138		
Mental health benefits	£13	£7	£13	£7		
Air quality regulation	£17	£12	£17	£12		
Recreation	£63	£59				
Global climate regulation	£19	£6				
Food production from allotments	£14	£3				
Biodiversity (non-use benefits only)	£4	£1				
Flood risk regulation	£2	£1				
Direct parks income	£13	£13			£13	£13
Adjustments	£0	£0			£0	£0
Gross asset value	£984	£263	£278	£157	£67	£15
Liabilities						
Parks services expenditure	£26	£26	£26	£26	£26	£26
Net-Value	**£959** to society	**£238** to society	**£253** in health benefits	**£132** in health benefits	**£42** to the Council	**-£10** to the Council
Benefits-Cost Ratio	***38.5 : 1***	***10.3 : 1***	***10.9 : 1***	***6.1 : 1***	***2.6 : 1***	***0.6 : 1***

Source: ***Author calculation***

5. Conclusions

This investigation shows just how important it is to account for natural capital and non-financial (social and environmental) values in general. It also shows how limited and insufficient conventional accounting is in measuring impacts on society and human wellbeing. When only accounting for the private costs and benefits as usually the case in conventional financial accounting, then Council-managed parks and greenspaces are stated as a net-liability to society as well as a net-expenditure to the Council. Making budget decisions for greenspace management purely based on conventional accounts can therefore lead to adverse consequences. Accounting for the value of natural capital gives us a much better estimate of the value Council-managed parks and greenspaces add to society.

The Council Tax uplift calculation in this investigation shows that, if investment in Council-managed natural capital declines, overall Council Tax income may well decline as well, even if this may only materialise in the medium to long-term. This means that reducing investment in natural capital could ultimately result in a decline in public coffers even if conventional accounting may initially indicate cost-savings. Hence, purely relying on conventional accounts when informing budget decisions affecting natural capital could easily result in unintended outcomes such as a net-decline in the Council income which means that other Council services may need to be reduced as well (in addition to significant natural capital benefits to society that could be lost when reducing investment in parks and greenspaces).

Economic valuation is sometimes criticised and rejected as being too rough and uncertain. But already the great British economist John Maynard Keynes said that *"it is better to be roughly right than precisely wrong."*[30] And that was exactly the aim of this assessment – to be roughly right by getting as close to the true natural capital value as possible rather than being precisely wrong by ignoring and neglecting value domains that are more difficult to quantify.

Ideally, natural capital accounts should be updated on an annual basis. However, the ONS acknowledges that annual physical changes to natural capital are often not significant and related environmental data is often not updated frequently enough to support annual natural capital accounts (ONS and Defra, 2017). Therefore, initially a 5-year cycle for updating natural capital accounts seems sensible for the purpose of monitoring both, physical and monetary changes over time.

The scientific evidence for valuing natural capital, on the other, is developing rather fast which improves the availability and quality of valuation studies and therefore the extent to which natural capital values can be assessed in monetary terms. This is a good argument for updating natural capital accounts more frequently throughout the period of fast-developing

[30] Originally: "It is better to be vaguely right than exactly wrong" (Read, 1898)

valuation approaches. In future assessments it may for example be possible to also quantify the monetary value of health benefits from gardening in allotments, the noise mitigation services of woodlands and local climate regulation services. A spatially explicit analysis is also possible to assess for example which communities in Birmingham benefit most (least) from natural capital.

Furthermore, it is possible to expand the assessment scope to all natural capital assets in Birmingham, including those that are not managed by the Council. This includes for example nature reserves managed by the Wildlife Trust. It is also possible to conduct a scenario analysis of how natural capital values would change under different investment and management regimes. The Future Parks Accelerator project provides a good opportunity window for such analysis.

6. Abbreviations

AQMA	Air Quality Management Area
BAP	Biodiversity Action Plan
BCR	Benefit-Cost Ratio
BHPS	British Household Panel Survey
C	Carbon
CEH	Centre for Ecology and Hydrology
CO_2	Carbon Dioxide
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food & Rural Affairs
GDP	Gross Development Product
GHG	Greenhouse Gas
GHQ	General Health Questionnaire
GIS	Geographic Information System
HLF	Heritage Lottery Funding
HPM	Hedonic Price Method
LLPG	Local Land and Property Gazetteer
LSOA	Lower Super Output Area
MENE	Monitor of Engagement with the Natural Environment
MET	Metabolic Equivalence of Task
NEWP	Natural Environment White Paper
NO_2	Nitrogen Dioxide
ONS	Office for National Statistics
ORVal	Outdoor Recreation Valuation (tool)
PM_x	Fine Particulates
POPI	Parks Operations Performance Information
QALY	Quality Adjusted Life Year
SO_2	Sulphur Dioxide
STPR	Social Time Preference Rate
TEV	Total Economic Value
WHO	World Health Organisation
WTP	Willingness-To-Pay

7. References

Ainsworth, B.E., Haskell, W.L., Herrmann, S.D., Meckes, N., Bassett, D.R., Tudor-Locke, C., Greer, J.L., Vezina, J., Whitt-Glover, M.C., Leon, A.S., 2011. 2011 Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc 43, 1575–1581. https://doi.org/10.1249/MSS.0b013e31821ece12

Alonso, I., Weston, K., Gregg, R., Morecroft, M., 2012. Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources (Natural England Research Report No. NERR043). Natural England.

Beale, S., Bending, M., Trueman, P., 2007. An Economic Analysis of Environmental Interventions That Promote Physical Activity. University of York: York Health Economics Consortium.

BEIS, 2019. Valuation of Energy Use and Greenhouse Gasses - Supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government. Department for Business, Energy & Industrial Strategy, London.

Birmingham City Council, 2017a. Budget for Birmingham 2017/18. Birmingham City Council, Birmingham.

Birmingham City Council, 2017b. 2016 Air Quality Annual Status Report (ASR). Birmingham City Council, Birmingham.

Birmingham City Council, 2013. Birmingham's Green Living Spaces Plan. Birmingham City Council, Birmingham.

Brander, L.M., Ghermandi, A., Kuik, O., Markandya, A., Nunes, P., Schaafsma, M., Wagtendonk, A., 2008. Scaling up ecosystem services values - methodology, applicability and a case study.

Brander, L.M., Koetse, M.J., 2011. The value of urban open space: Meta-analyses of contingent valuation and hedonic pricing results. Journal of Environmental Management 92, 2763–2773. https://doi.org/10.1016/j.jenvman.2011.06.019

Buccolieri, R., Gromke, C., Di Sabatino, S., Ruck, B., 2009. Aerodynamic effects of trees on pollutant concentration in street canyons. Science of The Total Environment 407, 5247–5256. https://doi.org/10.1016/j.scitotenv.2009.06.016

Butcher, W., Carey, P., Edmonds, R., Norton, L., Treweek, J., 2018. The UK Habitat Classification: Habitat Definitions Version 1.0. UK Habitat Classification Working Group, Exeter.

Centre for Mental Health, 2010. The economic and social costs of mental health problems in 2009/10. Centre for Mental Health, London.

Centre for Mental Health, 2003. The economic and social costs of mental illness (Policy Paper). Centre for Mental Health, London.

Cho, S.-H., Poudyal, N.C., Roberts, R.K., 2008. Spatial analysis of the amenity value of green open space. Ecological Economics 66, 403–416. https://doi.org/10.1016/j.ecolecon.2007.10.012

Christie, M., Hyde, T., Cooper, R., Fazey, I., Dennis, P., Warren, J., Colombo, S., Hanley., N., 2011. Economic Valuation of the Benefits of Ecosystem Services delivered by the UK Biodiversity Action Plan (Report to Defra No. SFFSD 0702). Aberystwyth University, London.

Church, A., Burgess, J., Ravenscroft, N., Bird, W., Blackstock, K., Brady, E., Crang, M., Fish, R., Gruffudd, P., Mourato, S., Pretty, J., Tolia-Kelly, D., Turner, K., Winter, 2011. UK National Ecosystem Assessment of Cultural Services, in: The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge.

Cook, R., 2006. A Study of Allotments and Small Land Plots: Benchmarking for Vegetable Food Crop Production (PhD Thesis). University of Glamorgan, Pontypridd.

Coombes, E., Jones, A.P., Hillsdon, M., 2010. The relationship of physical activity and overweight to objectively measured green space accessibility and use. Soc Sci Med 70, 816–822. https://doi.org/10.1016/j.socscimed.2009.11.020

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253–260. https://doi.org/10.1038/387253a0

Davies, L., Kwiatkowski, L., Gaston, K.J., Beck, H., Brett, H., Batty, M., Scholes, L., Wade, R., Sheate, W.R., Sadler, J., Perino, G., Andrews, B., Kontoleon, A., Bateman, I., Harris, J.A., Burgess, P., Cooper, N., Evans, S., Lyme, S., McKay, H.I., Metcalfe, R., Rogers, K., Simpson, L., Winn, J., 2011. UK National Ecosystem Assessment of Urban Ecosystems, in: The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge.

Day, B., Smith, G., 2018a. Outdoor Recreation Valuation (ORVal) Tool Version 2.0. Land, Environment, Economics and Policy (LEEP) Institute, Business School, University of Exeter, Exeter.

Day, B., Smith, G., 2018b. Outdoor Recreation Valuation (ORVal) User Guide Version 2.0 (User Guide). Land, Environment, Economics and Policy (LEEP) Institute, Business School, University of Exeter, Exeter.

Defra, 2017. Evidence Statement on the links between natural environments and human health (Evidence Statement). Department for Environment, Food and Rural Affairs, London.

Defra, 2007. An introductory guide to valuing ecosystem services.

Defra, 2005. Making space for water: Taking forward a new Government strategy for flood and coastal erosion risk management in England. Department for Environment, Food and Rural Affairs, London.

Department of Health, 2004. At least five a week - Evidence on the impact of physical activity and its relationship to health (A report from the Chief Medical Officer No. Gateway Ref: 2389). Department of Health, Physical Activity, Health Improvement and Prevention.

Eftec, 2017. A Study to Scope and Develop Urban Natural Capital Accounts for the UK. Economics for the Environment Consultancy Ltd, London.

Elliott, L.R., White, M.P., Taylor, A.H., Herbert, S., 2015. Energy expenditure on recreational visits to different natural environments. Social Science & Medicine 139, 53–60. https://doi.org/10.1016/j.socscimed.2015.06.038

European Commission, 2012. The Multifunctionality of Green Infrastructure, Science for Environmental Policy.

Garden Organic and Sustain, 2014. The benefits of gardening and food growing for health and wellbeing. London.

Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Forns, J., Plasència, A., Nieuwenhuijsen, M.J., 2015. Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review. International Journal of Environmental Research and Public Health 12, 4354–4379. https://doi.org/10.3390/ijerph120404354

Gibbons, S., Mourato, S., Resende, G.M., 2014. The Amenity Value of English Nature: A Hedonic Price Approach. Environ Resource Econ 57, 175–196. https://doi.org/10.1007/s10640-013-9664-9

Hanley, N., Willis, K., Powe, N., Anderson, M., 2002. Valuing the Benefits of Biodiversity in Forests. Social & Environmental Benefits of Forestry Phase 2 (Report to the Forestry Commission). Centre for Research in Environmental Appraisal and Management, University of Newcastle upon Tyne, Edinburgh.

HM Government, 2018. A Green Future: Our 25 Year Plan to Improve the Environment. HM Government, London.

HM Government, 2011. The Natural Choice: securing the value of nature (No. CM 8082).

HM Treasury, 2018. The Green Book - Central Government Guidance on Appraisal and Evaluation. HM Treasury, London.

Ho, C.-H., Payne, L., Orsega-Smith, E., Godbey, G., 2003. Parks, recreation and public health: parks and recreation improve the physical and mental health of our nation. (Research Update).: An article from: Parks & Recreation. National Recreation and Park Association.

Hölzinger, O., Grayson, N., Christie, M., Coles, R., 2013. Ecosystem Services Evaluation for Birmingham's Green Infrastructure. Birmingham City Council, Birmingham.

IPCC, 2014. Climate Change 2014: Synthesis Report. IPCC, Geneva, Switzerland.

Jones, L., Vieno, M., Morton, D., Cryle, P., Holland, M., Carnell, E., Nemitz, E., Hall, J., Beck, R., Reis, S., Pritchard, N., Hayes, F., Mills, G., Koshy, A., Dickie, I., 2017. Developing Estimates for the Valuation of Air Pollution Removal in Ecosystem Accounts (Final Report For Office for National Statistics). Centre for Ecology and Hydrology (CEH) in association with Economics for the Environment Consultancy Ltd (eftec) and EMRC, London.

Kuppuswamy, H., 2009. Improving health in cities using green infrastructure: A review. FORUM Ejournal 9, 63–76.

Lovasi, G.S., Quinn, J.W., Neckerman, K.M., Perzanowski, M.S., Rundle, A., 2008. Children living in areas with more street trees have lower asthma prevalence. Journal of Epidemiology and Community Health. https://doi.org/10.1136/jech.2007.071894

McPherson, E.G., Nowak, J.J., Rowan, A.R., 1994. Chicago's urban forest ecosystem - results of the Chicago Urban Forest Climate Project (General Technical Report No. NE-186). U.S. Department of Agriculture, Radnor.

Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being (Synthesis Report).

Morison, J., Matthews, R., Miller, G., Perks, M., Randle, T., Vanguelova, E., White, M., Yamulki, S., 2012. Understanding the carbon and greenhouse gas balance of forests in Britain (Forestry Commission Research Report). Forestry Commission, Edinburgh.

Morling, P., Comerford, E., Bateman, I., Beaumont, N., Bolt, K., Soest, D. van, Vause, J., 2010. Economic Assessment of Biodiversity (UK NEA Economic Analysis Report).

Mourato, S., Atkinson, G., Collins, M., Gibbons, S., MacKerron, G., Resende, G., 2010. Economic Analysis of Cultural Services (UK NEA Economic Analysis Report). London School of Economics and Political Science, London.

Natural Capital Committee, 2013. The State of Natural Capital: Towards a framework for measurement and valuation.

ONS, 2018a. UK natural capital: ecosystem accounts for urban areas (Statistical Bulletin). Office for National Statistics, Newport.

ONS, 2018b. Value of nature implicit in property prices – Hedonic Pricing Method (HPM) methodology note (Methodology Note). Office for National Statistics, Newport.

ONS, 2018c. UK air pollution removal: how much pollution does vegetation remove in your area? [WWW Document]. URL https://www.ons.gov.uk/economy/environmentalaccounts/articles/ukairpollutionre

movalhowmuchpollutiondoesvegetationremoveinyourarea/2018-07-30 (accessed 11.23.18).

ONS, 2012. Accounting for the value of nature in the UK - A roadmap for the development of natural capital accounts within the UK Environmental Accounts. Office for National Statistics, London.

ONS, Defra, 2017. Principles of Natural Capital Accounting. Office for National Statistics/Department for Environment, Food & Rural Affair, Newport/London.

Pitt, M., 2007. Learning Lessons from the 2007 floods (Interim Report).

Pretty, J.N., Barton, J., Colbeck, I., Hine, R., Mourato, S., MacKerron, G., Wood, C., 2011. UK National Ecosystem Assessment of Health Values, in: The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge.

Public Health England, 2017. Spatial Planning for Health: An evidence resource for planning and designing healthier places. Public Health England, London.

Pugh, T.A.M., MacKenzie, A.R., Whyatt, J.D., Hewitt, C.N., 2012. Effectiveness of Green Infrastructure for Improvement of Air Quality in Urban Street Canyons. Environ. Sci. Technol. 46, 7692–7699. https://doi.org/10.1021/es300826w

Read, C., 1898. Logic Deductive and Inductive.

Read, D.J., Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, C.C., Snowdon, P., 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 (The synthesis report). The Stationery Offi ce, Edinburgh.

Saraev, V., 2012. Economic benefits of greenspace: A critical assessment of evidence of net economic benefits (Research Report). Forestry Commission, Edinburgh.

Smith, D., 2010. Valuing housing and green spaces: Understanding local amenities, the built environment and house prices in London (GLAEconomics Working Paper). Greater London Authority, London.

Smith, P., Ashmore, M., Black, H., Burgess, P., Evans, C., Hails, R., Potts, S., Quine, T., Thomson, A., Biesmeijer, K., Breeze, T., Broadmeadow, M., Ferrier, R., Freer, J., Hansom, J., Haygarth, P., Hesketh, H., Hicks, K., Johnson, A., Kay, D., Kunin, W., Lilly, A., May, L., Memmott, J., Orr, H., Pickup, R., Purse, B., Squire, G., 2011. UK National Ecosystem Assessment of Regulating Services, in: The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge.

Smithers, R., Korkeala, O., Whiteley, G., Brace, S., Holmes, B., 2016. Valuing flood-regulation services for inclusion in the UK ecosystem accounts (Final report for UK Office for National Statistics (ONS)). Ricardo Energy & Environment, Didcot.

Stansfeld, S., Clark, C., Bebbington, P., King, M., Jenkins, R., Hinchliffe, S., 2016. Common mental disorders, in: McManus S, Bebbington P, Jenkins R, Brugha T. (Eds.) Mental Health and Wellbeing in England: Adult Psychiatric Morbidity Survey 2014. NHS Digital, Leeds.

Stern, N., 2006. Stern Review on The Economics of Climate Change. HM Treasury, London.

Tempesta, T., 2014. Benefits and costs of urban parks.

UK NEA, 2011a. UK National Ecosystem Assessment: Technical Report. UNEP-WCMC, Cambridge.

UK NEA, 2011b. UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge.

van Oudenhoven, A.P.E., Petz, K., Alkemade, R., Hein, L., de Groot, R.S., 2012. Framework for systematic indicator selection to assess effects of land management on ecosystem services. Ecological Indicators 21, 110–122. https://doi.org/10.1016/j.ecolind.2012.01.012

Vivid Economics, 2017. Natural Capital Accounts for Public Green Space in London. Greater London Authority, London.

White, M.P., Alcock, I., Wheeler, B.W., Depledge, M.H., 2013. Would You Be Happier Living in a Greener Urban Area? A Fixed-Effects Analysis of Panel Data. Psychol Sci 24, 920–928. https://doi.org/10.1177/0956797612464659

White, M.P., Elliott, L.R., Taylor, T., Wheeler, B.W., Spencer, A., Bone, A., Depledge, M.H., Fleming, L.E., 2016. Recreational physical activity in natural environments and implications for health: A population based cross-sectional study in England. Preventive Medicine 91, 383–388. https://doi.org/10.1016/j.ypmed.2016.08.023

WHO, 1948. Preamble to the Constitution of the World Health Organization. Presented at the International Health Conference, World Health Organisation, New York, United States of America.

Willis, K., Garrod, G., Scarpa, R., Powe, N., Lovett, A., Bateman, I.J., Hanley, N., Macmillan, D.C., 2003. Social & Environmental Benefits of Forestry Phase 2: The Social and Environmental Benefits of Forests in Great Britain (Report to Forestry Commission). Centre for Research in Environmental Appraisal & Management University of Newcastle, Edinburgh.

Woodcock, J., Franco, O.H., Orsini, N., Roberts, I., 2011. Non-vigorous physical activity and all-cause mortality: systematic review and meta-analysis of cohort studies. Int J Epidemiol 40, 121–138. https://doi.org/10.1093/ije/dyq104

Woodland Trust, 2012. Urban Air Quality. Woodland Trust, Lincolnshire.

WWF, 2018. Living Planet Report 2018: Aiming Higher. WWF, Gland.