The Right Tool at the Right Time: Applying Natural Capital and Ecosystem Services Valuation for Decision-making Purposes – Experiences from Birmingham

by

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Abstract

Natural capital (geology, soil, air, water and all living things) and the ecosystem services it provides such as recreational opportunities, aesthetics and air, water and climate regulation are of critical importance for human wellbeing and economic prosperity. Despite acknowledgement of their importance, natural capital is often degraded and in continuing decline; both, in the UK and worldwide. Because the unregulated market is failing to lead itself to the sustainable use and management of these valuable natural capital assets, it is the duty of Government organisations to step in and set regulations and incentives to better protect and enhance natural capital.

To enable decision-makers to make informed decisions with respect to environmental policies and interventions, it is of great importance to reveal the so often hidden values of natural capital. Such valuation evidence is not only needed at the global and national scale, but also at the local scale where most land-use decisions take place; such as in Birmingham, UK, which has been chosen as a case study for this thesis.

Holistic natural capital and ecosystem services valuation is challenging and imperfect. In the past, academics were not particularly successful in working together with decision-makers to produce the valuation evidence the latter require to inform their decisions; despite remarkable progress in valuation research. The aim of this investigation was to bridge this ‘implementation gap’ between valuation evidence generated by academia and evidence demanded by local decision makers.

Four different valuation tools have been applied in the local policy context of Birmingham. This required the adaptation of three existing valuation tools to be suitable for the local context; namely ecosystem services mapping, Ecosystem Assessment, and Natural Capital Accounting. The last valuation tool, the Natural Capital Planning Tool (NCPT), needed to be developed from scratch because a comparable tool to assess the impact of planning decisions on ecosystem services did not exist. The created evidence and tools have for example informed Birmingham’s green infrastructure strategy and the design of a large-scale development on Birmingham’s green belt. It has also revealed that Birmingham’s parks and greenspaces services are good value for money as the benefits significantly outweigh the costs.

A demand-driven approach has been chosen when developing, adapting and applying these valuation tools to ensure that they meet the requirements and everyday circumstances of the decision makers. The research has shown that the ‘implementation gap’ can be narrowed by developing fit-for-purpose natural capital and ecosystem services valuation evidence and tools as long as they are developed in close collaboration with local decision makers and stakeholders.

Declaration

I hereby declare that this thesis is my own original work except where stated otherwise by reference in the text. It has not been submitted, in whole or in part, for any other degree or qualification at this or any other university. Further, I have acknowledged and correctly referenced the work of others.

This thesis is dedicated to

my wife and best friend Danying Li and my mother Marion Sordon.

Without your unconditional love and support throughout my life and academic journey,

this thesis would not have been possible.

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Oliver Hölzinger

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List of Abbreviations

25 YEP	25 Year Environment Plan
ALGE	Association of Local Government Ecologists
ALI	Assessment Level Indicator
ANGSt	Accessible Natural Greenspace Standard
ASNW	Ancient Semi-Natural Woodland
BAP	Biodiversity Action Plan
BCR	Benefit-Cost Ratio
BEIS	Department of Business, Energy & Industrial Strategy
CBA	Cost Benefit Analysis
CEA	Cost-Effectiveness Analysis
CEH	Centre for Ecology and Hydrology
CEV	Corporate Ecosystem Valuation
CO_2	Carbon Dioxide
COP	Conference Of Parties
DCLG	Department for Communities and Local Government
Defra	Department for Environment, Food and Rural Affairs
DIS	Development Impact Score
DMV	Deliberative Monetary Valuation
EA	Ecosystem Assessment
EC	European Commission
Eftec	Economics for the Environment Consultancy
EMEP4UK	European Monitoring and Evaluation Program Unified Model for the UK
ES	Ecosystem Services
ESIS	Ecosystem Services Impact Score
ESSDM	Ecosystem Services Supply and Demand Map
GDP	Gross Domestic Product
GHG	Greenhouse Gasses
GI	Green Infrastructure
GIS	Geographic Information System
HLF	Heritage Lottery Fund

HPM	Hedonic Price Method
ILI	Input Level Indicator
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
JNCC	Joint Nature Conservation Committee
LSOA	Lower Super Output Area
MA	Millennium Ecosystem Assessment
MCDA	Multi-Criteria Decision Analysis
MENE	Monitor of Engagement with the Natural Environment
MHCLG	Ministry of Housing, Communities and Local Government
NC	Natural Capital
NCA	Natural Capital Accounts
NCC	Natural Capital Committee
NCCT	Natural Capital City Tool
NCPT	Natural Capital Planning Tool
NERC	Natural Environment Research Council
NEWP	Natural Environment White Paper
NIA	Nature Improvement Area
NPPF	National Planning Policy Framework
NPPG	National Planning Practice Guidance
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
ORVal	Outdoor Recreation Valuation
PAWS	Plantation on Ancient Woodland Site
PES	Payments for Ecosystem Services
$PM_{2.5}$	Fine Particulate Matter
POPI	Parks Operations Performance Information
PPPP	Policy, Plan, Project, Programme
QALY	Quality Adjusted Life Year
RICS	Royal Institution of Chartered Surveyors
ROAMEF	Rationale, Objectives, Appraisal, Monitoring, Evaluation and Feedback

RSPB	Royal Society for the Protection of Birds
RTPI	Royal Town Planning Institute
SEEA	System of Environmental-Economic Accounting
SMART	Specific, Measurable, Attainable, Relevant and Time-bound
SPD	Supplementary Planning Document
SROI	Social Return On Investment
STPR	Social Time Preference Rate
SUE	Sustainable Urban Extension
TABLES	Tools – Applications, Benefits and Linkages for Ecosystem Science
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Value
TWT	The Wildlife Trusts
UHIE	Urban Heat Island Effect
UK NEA	UK National Ecosystem Assessment
UK NEAFO	UK National Ecosystem Assessment Follow-On
UK	United Kingdom
UN	United Nations
UNEP-WCMC	UN Environment Programme World Conservation Monitoring Centre
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organisation
WTA	Willingness-To-Accept
WTP	Willingness-To-Pay
WWF	World Wide Fund for Nature

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1 Chapter One: Introduction

1.1 Thesis Overview

1.1.1 Aims and Objectives

It is widely recognised that, whilst natural capital (hereafter NC) and ecosystem services (hereafter ES) valuation has a great potential to inform decision-making, there is still an 'implementation gap' between the evidence produced by science and the evidence demanded to inform practical decision-making (Bastian et al., 2012; Cowling et al., 2008; Daily et al., 2009; Daily and Matson, 2008; Kroll et al., 2012; Laurans et al., 2013; Laurans and Mermet, 2014; Layke, 2009; Levrel et al., 2017; Nahuelhual et al., 2015; Primmer and Furman, 2012; Shi, 2004). In this thesis I posit the hypothesis that NC and ES valuation does not yet more widely inform decision-making because relevant valuation evidence is not only unfit-for-purpose but not available at the appropriate spatial scale where decisions take place.

The aim of this investigation was: To bridge the 'implementation gap' by developing and adapting 'fit-for-purpose' NC and ES valuation tools designed specifically to support decision-making at relevant scales were land-use decisions take place. The objectives were:

1. To provide NC/ES valuation evidence based on and driven by decision-makers' demand;
2. To adopt and develop relevant valuation tools suitable for the relevant decision-making context in Birmingham; and
3. To contextualise how these valuation tools are positioned along stages of the decision-making process and geographical scales.

1.1.2 Thesis Chapters

This chapter (Chapter One) provides a general introduction to the concepts of NC and ES and summarises evidence of NC and ES degradation due to human activity in recent decades. Given that NC and ES valuation is grounded in ecological economic theory, it also provides an economic perspective on environmental problems where they are often seen as the result of market failure. This is followed by an introduction to NC and ES valuation methods and tools.

The chapter is completed by an analysis of the decision- and policy-making process and opportunities to inform this process through NC/ES valuation (tools). The following chapters outline relevant valuation tools and their application in Birmingham.

Chapter Two shows a spatial analysis of ES supply and demand at the city-scale. Together with stakeholders, a series of 6 ES supply and demand maps has been produced. Combined, they provide a 'multiple challenge map for Birmingham' indicating both; areas that have a particularly high level of ES provision ('ES hotspots') and areas where the enhanced provision of ES would be particularly beneficial.

Chapter Three outlines an Ecosystem Assessment for Birmingham; recognising that an assessment of ES value is not only beneficial at the (inter)national scale, but also at the local authority scale where many land-use decisions take place. To my knowledge this was the first city-wide Ecosystem Assessment in the UK. The Ecosystem Assessment investigates the value of 8 ES across 4 broad habitat types.

Chapter Four introduces Natural Capital Accounts and a Health Economic Assessment for NC assets managed by Birmingham City Council at the sub-city scale. The assessment reveals the NC value to society as a whole, but also to the Council coffers such as through Council Tax uplift and in health benefits. To my knowledge this was the first time that Council Tax uplift has been calculated. Furthermore, the accounts indicate the 'value for money' for investment in Council-managed NC.

Chapter Five outlines the development and application of a new valuation tool specifically designed for the planning context; the Natural Capital Planning Tool (NCPT). The NCPT was designed to quantify the impact of proposed land-use changes on 10 different ES at the project scale. The tool was for example used to assess the impact of a live masterplan in the north-east of Birmingham.

In Chapter Six the different NC and ES tools were contextualised. Here, it is indicated at which scales these NC and ES valuation tools are applicable and which stages of the decision-making process they inform.

1.2 Natural Capital and Ecosystem Services

The NC concept essentially describes the natural environment surrounding us as a valuable resource or range of assets all humans depend upon. A commonly used definition is the one proposed by the World Forum on NC:

> *"Natural capital can be defined as the world's stocks of natural assets which include geology, soil, air, water and all living things."*[1]

Whilst a universally agreed definition is yet to be agreed, common definitions are often functionally similar (UNEP-WCMC, 2018). The UK Government, for example, defines NC in a more elaborative way:

> *"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 term NC was first coined by the economist E. F. Schumacher in 1973 (Schumacher and Porritt, 1993). Later, it was further developed by ecological economists as a critique to conventional economic theory (see e.g. Costanza and Daly, 1992). NC can be seen as part of five forms of capital required to create wealth (Forum for the Future, 2018). The other four capitals are:

- Human capital (labour including health, knowledge, skills, motivation, etc.);
- Social capital (e.g. human relationships, partnerships and co-operation);
- Manufactured capital (material goods such as buildings, infrastructure and technologies); and
- Financial capital (e.g. cash, shares and bonds).

[1] https://naturalcapitalforum.com/about/ (accessed: 22/11/2019).

NC can be seen as the most fundamental of capitals because it is the basis for all other capitals (Figure 1.1) (Forum for the Future, 2018). Hence, it could be argued that NC is not just the basis for the generation of wealth but also for life itself.

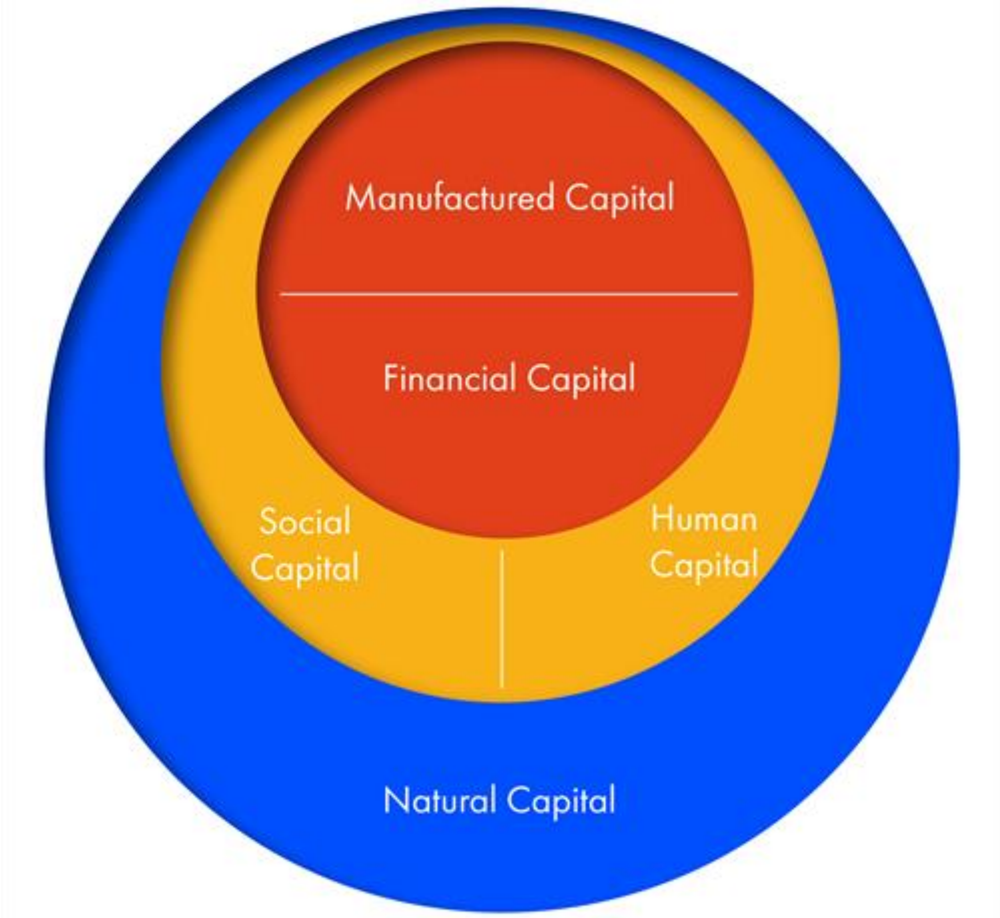


Figure 1.1 Five Capitals Model. The figure illustrates five types of sustainable capital from where people derive the goods and services they need to improve the quality of their lives. Here, manufactured and financial capital depends on the availability of social and human capital which themselves depend on the availability of natural capital. *Source: Adopted from Forum for the Future (2018).*

The flow of goods and services provided by NC is called ES which is often defined as *"the benefits people obtain from ecosystems"* (Millennium Ecosystem Assessment, 2005, p. V) such as food, air quality regulation and spaces for recreation. ESs are commonly grouped into four categories: provisioning, regulating, cultural and supporting services (Millennium Ecosystem Assessment, 2005).

In this framework (Figure 1.2), only the former three categories directly provide benefits to people whilst the latter, as the name suggests, supports (or enables) the provision of these 'final' ESs (Atkinson et al., 2012). It should also be acknowledged that biodiversity underpins the provision of all ES and that for ES to be realised, usually some form of human input is required such as labour and agricultural machinery to plant, manage and harvest food crops (UK NEA, 2011a).

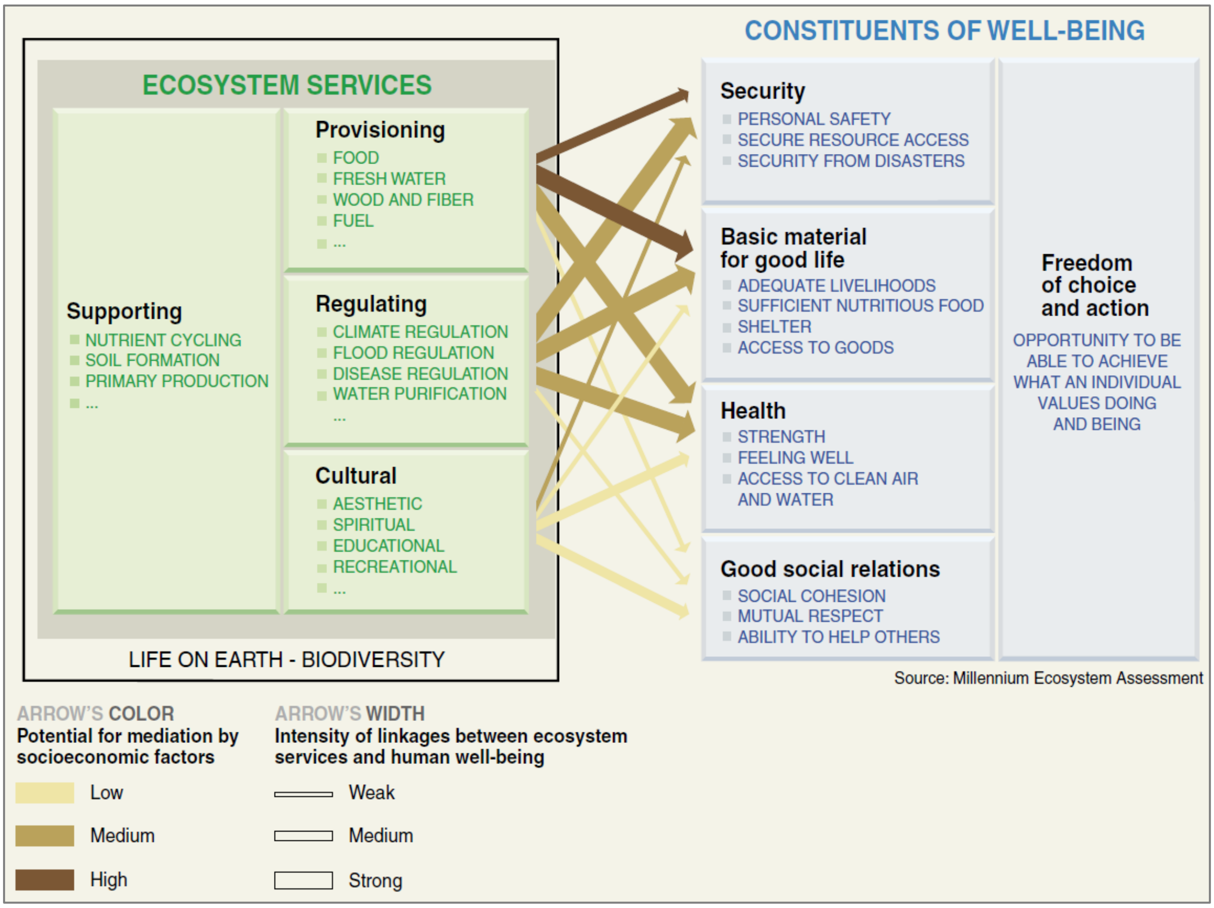


Figure 1.2 Linkages Between Ecosystem Services and Human Wellbeing. The figure depicts the strength of linkages between categories of ecosystem services and components of human wellbeing that are commonly encountered, and includes indications of the extent to which it is possible for socioeconomic factors to mediate the linkage. For example, if it is possible to purchase a substitute for a degraded ecosystem service, then there is a high potential for mediation. The strength of the linkages and the potential for mediation differ in different ecosystems and regions. In addition to the influence of ecosystem services on human wellbeing depicted here, other factors—including other environmental factors as well as economic, social, technological, and cultural factors—influence human wellbeing, and ecosystems are in turn affected by changes in human wellbeing. *Source: Adopted from Millennium Ecosystem Assessment (2005, p. vi).*

If managed sustainably, then the stock of NC provides a sustainable flow of ES which finally benefit human wellbeing. However, if the quality and quantity of the NC stock declines (Section 1.3), then the ES that flow from this NC stock also decline, with negative consequences for human wellbeing. This is why it is important to positively manage and re-invest in NC – not just for its own sake but to secure the manifold benefits people receive from the NC.

1.3 The State of Natural Capital and Ecosystem Services

At the global level, one of the milestones in bringing the importance and value of NC and the ES it provides to the attention of a wider audience, also beyond academia, was the publication of 'The value of the world's ecosystem services and natural capital' in Nature (Costanza et al., 1997). Costanza et al. (1997) estimated that the total value of the World's NC was in the range of US$16 – 54 trillion (nominal), stressing that this should be considered a minimum estimate. For comparison, the global Gross National Product at that time was in the order of US$18 trillion.

The authors also highlighted that *"the services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system."* (Costanza et al., 1997, p. 253). But *"because ecosystem services are largely outside the market and uncertain, they are too often ignored or undervalued…"* (Costanza et al., 1997, p. 259). The authors call for better acknowledgement and incorporation of such values into project assessments and accounting systems.

In light of this increasing recognition of the value and vulnerability of NC globally, the Millennium Ecosystem Assessment (MA) was called for by United Nations (UN) Secretary-General Kofi Annan in 2000 with the objective to assess the consequences of ecosystem change for human wellbeing. The assessment involved the work of 1,360 experts worldwide and was published in 2005; putting the issues of NC and ES importance and decline firmly on the agenda of the global political stage.

Like the Intergovernmental Panel on Climate Change (IPCC) for climate change, the MA synthesised scientific findings from around the world for a wider audience including decision-makers. The MA found that, whilst ES contributed greatly to economic development and human wellbeing over the past 50 years, human impact has led to the degradation of many ES and substantial and largely irreversible losses to biodiversity. Significant changes in politics, institutions and practices would be required to reverse this degradation at a time where demand for ES is increasing (Millennium Ecosystem Assessment, 2005).

Developing out of the MA, The Economics of Ecosystems and Biodiversity (TEEB) initiative also drew attention to the value and benefits biodiversity and ecosystems provide to the economy and society (TEEB, 2010a). It also produced guidance to encourage more sustainable management of biodiversity and ecosystems for a range of stakeholders including local and regional policy makers and businesses (TEEB, 2010b, 2010c).

In the UK where my case study sites in Birmingham are located, the UK National Ecosystem Assessment (UK NEA, 2011b) paved the way for better acknowledgement and integration of NC and ES values. The 2-year project was the first systematic assessment of how the UK's environment benefits the economy and society as a whole. These are some of the key messages of the UK NEA, 2011b (p. 5):

- *"The natural world, its biodiversity and its constituent ecosystems are critically important to our wellbeing and economic prosperity, but are consistently undervalued in conventional economic analyses and decision making."*
- *"Ecosystems and ecosystem services, and the ways people benefit from them, have changed markedly in the past 60 years, driven by changes in society."*
- *Of the range of services delivered in the UK […], about 30% have been assessed as currently declining. Many others are in a reduced or degraded state…"*
- *"The UK population will continue to grow, and its demands and expectations continue to evolve. This is likely to increase pressures on ES in a future where climate change will have an accelerating impact…"*
- *"Actions taken and decisions made now will have consequences far into the future for ecosystems, ecosystem services and human wellbeing. It is important that these are understood, so that we can make the best possible choices, not just for society now but also for future generations. […] Recognising the value of ES more fully would allow the UK to move towards a more sustainable future, in which the benefits of ES are better realised and more equitably distributed."*
- *"A move to sustainable development will require an appropriate mixture of regulations, technology, financial investment and education, as well as changes in individual and societal behaviour and adoption of a more integrated, rather than conventional sectoral, approach to ecosystem management."*

The UK NEA identified a range of drivers of change that led to the decline and degradation of many NC asset types and ES. These include (1) habitat and land-use change due to the expansion of agricultural land and development linked to population growth; (2) pollution from industry and transport; (3) nutrient enrichment due to agricultural intensification; and (4) the overexploitation of natural resources such as through overfishing. In the future, climate change would further add to the pressures on NC and ES (Winn et al., 2011).

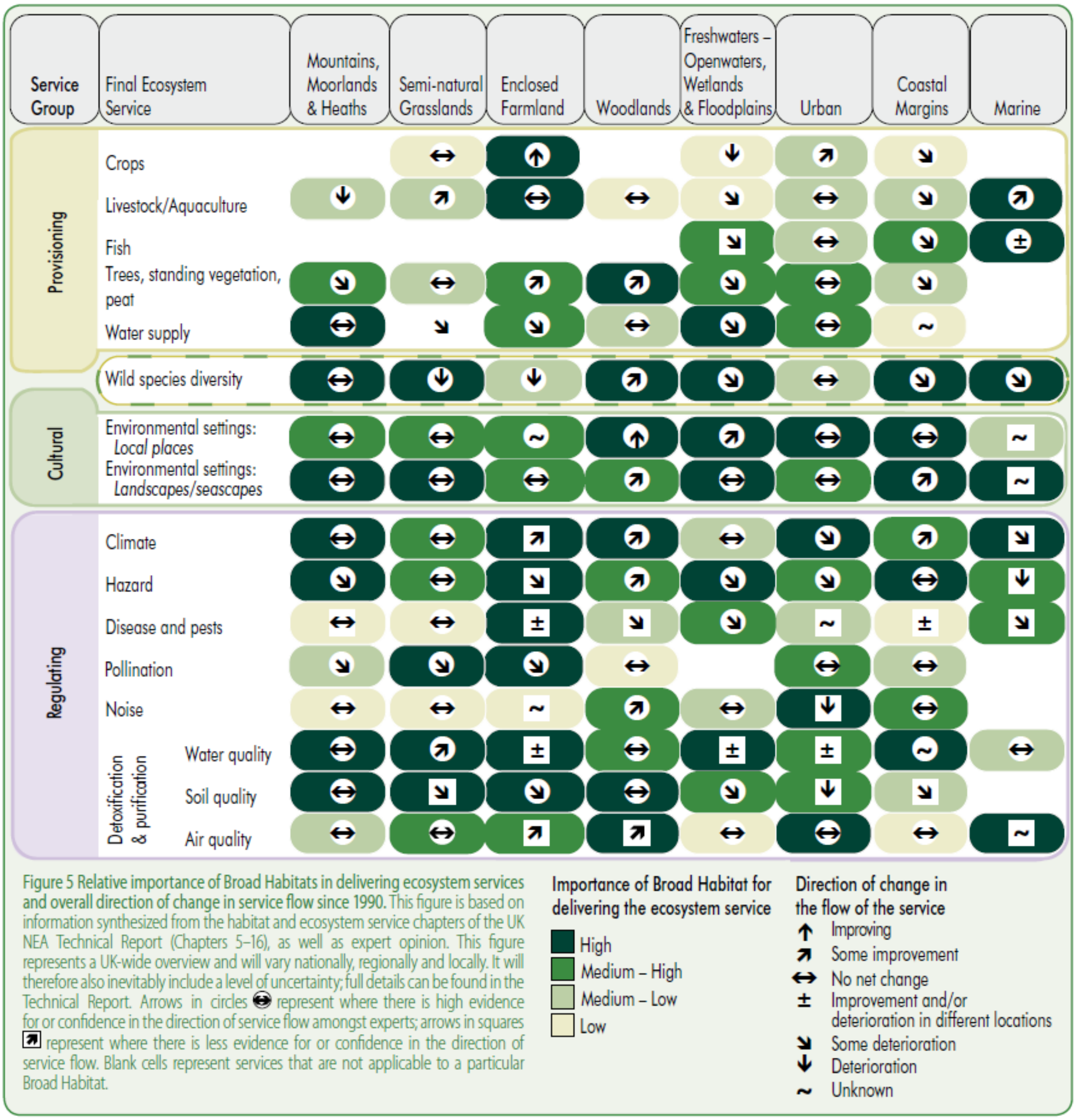


Figure 1.3 Relative Importance of UK Broad Habitats in Delivering Ecosystem Services and Overall Direction of Change in Service Flow 1990-2010. *Source: UK NEA (2011b, p. 11).*

Whilst policies such as the Clean Air Act 1956 and agri-environment schemes have helped to mitigate, and in some cases reverse, negative impacts, further efforts would be required to halt and reverse the degradation of NC and ES including stronger regulation, legislation and more research on the linkages between indirect and direct drivers on environmental change (Winn et al., 2011).

In light of the rapidly improving evidence base and increasing recognition of the importance and value of NC and ESs internationally and in the UK (e.g. Costanza et al., 1997; HM Government, 2018; HM Treasury, 2018; Millennium Ecosystem Assessment, 2005; TEEB, 2010a; UK NEA, 2011b), the concepts have gained increasing attention and traction in academia (e.g. Boyd and Banzhaf, 2007; Costanza, 2000; Daly and Farley, 2003; de Groot et al., 2010; Dickie et al., 2014; Fisher et al., 2009; Turner and Daily, 2008), national and international Governments (e.g. Defra, 2017; European Commission, 2011; European Union, 2011; HM Government, 2011; HM Treasury, 2018; ONS and Defra, 2017; UN et al., 2014), the business world (e.g. Eftec, 2015; NCC, 2016; WBCSD, 2011) and by third sector organisations (e.g. RSPB et al., 2013; RSPB and TWT, 2015; WWF, 2018).

1.3.1 The UK Government Response

The UK Government responded to the emerging evidence on NC and ES value and decline through a range of high-level policies and initiatives. This includes the publication of the Natural Environment White Paper (NEWP) 'The Natural Choice: securing the value of nature' (HM Government, 2011) published alongside the UK NEA (2011b). It states that

> *"The Government wants this to be the first generation to leave the natural environment of England in a better state than it inherited."*
> (HM Government, 2011, p. 3)

The NEWP pledges (1) to mainstream the value of nature across society; (2) facilitate greater local action to protect and improve nature such as through the creation of Nature Improvement Areas (NIAs) (see also Hölzinger et al., 2013a); (3) greening the economy; (4) strengthening the connection between people and nature; and (5) showing leadership internationally to protect and enhance NC. It also makes a commitment to *"put natural capital at the heart of government accounting"* (HM Government, 2011, p. 36) which subsequently lead to the development of national (ONS, 2019a) and sub-national NC Accounts (Sunderland et al., 2019) by Government institutions.

Another commitment of the NEWP was to establish a new body to provide advice to the Government on the sustainable use of NC and *"to put the value of England's natural capital at the heart of our economic thinking"* (HM Government, 2011, p. 35). As a response, the Natural Capital Committee was established in 2012. The Committee consists of seven experts[2] and has so far published six annual 'State of Natural Capital' reports, providing independent Government advice on NC management and policy (e.g. NCC, 2019, 2013). It also published practical guidance documents such as a NC workbook on how to use the NC Approach in practice (NCC, 2017).

The NCC also informed the most recent key policy document: 'A Green Future: Our 25 Year Plan to Improve the Environment' (HM Government, 2018). The 25 YEP sets out a range of actions to *"help the natural world regain and retain good health"* (HM Government, 2018, p. 9). The document identified six key policy themes:

1. Sustainable land-use and management;
2. Nature recovery and enhancements to the beauty of landscapes;
3. Improving people's health and wellbeing by better connecting them with nature;
4. Improving resource efficiency as well as waste and pollution reduction;
5. Securing clean, productive and biodiverse seas and oceans; and
6. The protection and enhancement of the global environment.

Some of the specific policies most relevant within scope of this thesis include:

- The pledge to embed an environmental net-gain principle for new developments (Chapter 5);
- The promotion of health and wellbeing benefits through contact with nature including the consideration of delivering mental health services through environmental therapies (Chapters 4); and
- Greening towns and cities (Chapters 2, 3 and 4).

The 25 YEP pledges to review progress towards the articulated goals with annual assessments against clearly defined metrics. It also pledges to create an independent body to hold the

[2] Professor Dieter Helm (Chairman), Professor Christopher Collins, Professor Colin Mayer, Professor Ian Bateman, Professor Kathy Willis, Professor Melanie Austen and Professor Paul Leinster (as off 25/11/2019)

Government to account for its implementation. In the 25 YEP, the Government acknowledges that:

> *"In the past, our failure to understand the full value of the benefits offered by the environment and cultural heritage has seen us make poor choices. […] The value of natural capital is routinely understated."*
> (HM Government, 2018, p. 19)

It also aimed to improve the understanding and valuation of the benefits of NC; an objective which also runs through this thesis. This gives me confidence in its relevance and contribution to science and practical decision-making alike.

The issue of NC and ES valuation, management and enhancement also spills over into policies not primarily focused on the natural environment. In its Industrial Strategy White Paper 'building a Britain fit for the future', the Government pledges to *"…work not just to preserve, but to enhance our natural capital"* (HM Government, 2017, p. 135). In its National Planning Policy Framework (NPPF), the Ministry of Housing, Communities & Local Government states that *"Planning policies and decisions should contribute to and enhance the natural and local environment by […] recognising the intrinsic character and beauty of the countryside, and the wider benefits from natural capital and ecosystem services…"* (MHCLG, 2018, para. 170). The links between the natural environment and human health are also increasingly recognised (Defra, 2017; Public Health England, 2017). Furthermore, the Government updated guidance on how to value nature in policy appraisals in its Green Book (HM Treasury, 2018).

1.4 Environmental Problems and Market Failure

From an economic perspective, environmental problems such as the overexploitation or degradation of NC is often described as the result of market failure. This section provides a brief, non-technical introduction to environmental problems from an economic perspective and is based on standard ecological economic theory (see for example Costanza et al., 2014; Shmelev, 2012). This section is partially based on Daly and Farley (2011).

Economics can be defined as *"the study of the allocation of limited, or scarce, resources among alternative, competing ends."* (Daly and Farley, 2011, p. 3). Given that the resources of the planet are scarce, we usually have to choose amongst competing alternatives. In standard neoclassical economic theory, humans are assumed to maximise their own welfare or utility based on pure self-interest.

In neoclassical theory, the market is optimised when the allocation of goods and services across society is pareto efficient; a situation in which no change to the allocation of resources makes at least one person better off without making anyone else worse off. Based on the pure self-interest of market participants, supply and demand will lead itself to a pareto efficiency equilibrium through the 'invisible hand of the market'. However, this theoretical model applies restrictive assumptions including: (1) all transactions are rational; (2) all market-relevant information is free and complete; (3) there are no transaction costs such as administration/negotiation costs; (4) no market participants have market power such as in a monopoly; (5) all goods are market goods; and (6) all transactions are voluntary. In this model, the market (supply and demand) ensures the efficient allocation of goods and services across society.[3] But because the assumptions of this model are so restrictive, such a market cannot exist in reality. With respect to environmental problems, the latter two assumptions (exclusively voluntary transactions and market goods) are particularly relevant.

Market goods are characterised by both, excludability and rivalry in consumption. Excludability means that someone can have exclusive ownership of that good and can choose to exclude others from using it. Rivalry in consumption means that a good can only be used once at the same time. An example for a market good is an apple. I can prevent others using the apple by for example storing it in my home (excludability). The apple can also only be consumed once so if I consume it no one else can (rivalry in consumption). Another characteristic to consider is congestibility where a good appears non-rival at times and rival at others (Daly and Farley, 2011). If someone is alone at a beach it may not bother him/her if someone else joins them on the beach. But it may well diminish their experience (utility) when thousands of others join and the beach becomes overcrowded.

One problem from an economic perspective is that many goods, especially environmental goods, do not have (all) characteristics of market goods. In these cases, the unregulated

[3] It should also be noted that this model does not consider issues such as wealth distribution or whether efficiency is used for something good or bad – it is 'value-free'. A situation where few people are very wealthy and many are very poor can still be pareto efficient, for example. I will not outline these issues here in more detail (see for example Daly and Farley, 2011).

market forces will not efficiently allocate these goods or provide them at all – the market fails. Deviations from market-goods are illustrated in Table 1.1. The most relevant deviations with respect to environmental problems – open access regimes and pure public goods – are further outlined below.

Table 1.1 The Market Relevance of Excludability, Rivalry in Consumption and Congestibility. The table categorises different types of goods depending on whether they are excludable or not and whether they are rival, non-rival or congestible goods. It also provides examples for each type of good. *Source: Daly and Farley (2011, p. 169).*

	Excludable	Nonexcludable
Rival	Market goods; food, clothes, cars, houses, waste absorption capacity when pollution is regulated.	Open access regimes ("tragedy of the commons"), e.g., ocean fisheries, logging of unprotected forests, air pollution, waste absorption capacity when pollution is unregulated
Nonrival	Potential market good, but if so, people consume less than they should (i.e., marginal benefits remain greater than marginal costs); e.g., information, cable TV, technology.	Pure public good, e.g., lighthouses, streetlights, national defense, most ecosystem services
Congestible	Toll or club goods: Market goods when scarce, zero marginal value when abundant. Greatest efficiency occurs when price fluctuates according to usage, or if clubs are formed that prevent the resource from becoming scarce; e.g., ski resorts, toll roads country clubs.	Open access regimes: Only efficient to make them excludable (i.e., to limit access) during periods of high use; e.g., non-toll roads, public beaches, national parks

1.4.1 Open Access Regimes

Open access regimes are characterised by rivalry but are nonexcludable. A commonly cited example in this respect is 'the tragedy of the commons' (Hardin, 1968). In the past it was common for English villages to have a plot of land the whole village can use for grazing cattle. If the grass of the common grows fast enough to feed 50 cows indefinitely and there are 50 villagers with 1 cow each using the common then it is used sustainably. However, because access to the common was unrestricted (nonexcludability) there may well be an incentive for villagers to buy additional cows. But because the common can only feed 50 cows sustainably and not 51, the common becomes overgrazed and all cows become thinner and less productive in terms of milk/meat production. In this situation the villager with 2 cows keeps the benefits (additional produce from two cows) for herself whilst the costs (slightly smaller produce for each cow) is shared amongst all villagers. And if other villagers act similarly by adding more cows to the common, the common eventually becomes overgrazed to an extent where many cows will die (not necessarily the ones of villagers who added more than one cow) because there is not enough grass to feed them. In this case, the rational self-interest of each individual leads to everyone being worse off rather than generating a pareto efficient situation.[4]

Whilst this problem for a village common is comparatively easy to solve (the villagers can agree among themselves to only have one cow each or the common is divided amongst the villagers so everyone has their own parcel), it is more difficult for other open access regimes where property rights cannot easily be allocated or enforced. Ocean fish is an example. International waters do not have property rights allocated and even if that was the case fish would cross these borders so overfishing in one parcel would affect fish stocks in neighbouring parcels, too. And even if international treaties to regulate fishing are in place, these are usually of voluntary nature and difficult to enforce. Hence, the rational self-interest of individuals (or nations) can easily lead to overfishing and even the collapse of fish stocks. Other examples are air pollution and greenhouse gasses (GHG) emissions where the costs of pollution/emissions are shared across society; more locally for air pollution but globally for GHG emissions.

1.4.2 Public Goods

Pure public goods (simply public goods hereafter) are characterised by both, non-rivalry in consumption and nonexcludability. Everyone can use a public good regardless of who produces (and crucially pays) for it. Public goods are worth producing as long as all individuals together are willing to pay for it. Or more specifically, as long as the marginal costs of producing another unit of the public good do not exceed the marginal benefits of its production. But because there is no rivalry in consuming public goods, the unregulated market will only produce public goods to the extent one individual is willing to pay for it because all others can benefit from it as ‘free-riders’. This inevitably leads to an underproduction with public goods. And if no one is willing to pay for a public good, because

[4] It should be noted that the often cited ‘tragedy of the commons’ is not actually an open access regime as only cows of villagers are allowed to graze here whilst cows from people outside the community are indeed excluded.

for each individual, the marginal costs exceed the marginal benefits, the public good would simply not be provided at all.

Many ES fall within this category. Let's take the example of a piece of woodland. As long as the land is managed as woodland it would probably produce timber, but also a wide range of other valuable ES such as climate regulation, air quality regulation, flood regulation, recreational opportunities and others. If the land was converted to intensively managed agricultural land, it would produce food crops but provide little in terms of other ES (see for example UK NEA, 2011b).

Whilst the provisioning ES (food and timber) are market goods, the other regulating and cultural ES mentioned are effectively public goods. That means that, if the land-owner can earn more income from managing the land for food production than for timber production, it would be a rational choice to do so even if this would mean that society as a whole would lose significant ES value because the public goods attached to the woodland would be lost. And because the landowner cannot exclude others from benefiting from the public good ES, they would have little incentive to compensate the landowner for producing these goods as they can equally benefit as 'free-riders' without paying.

The marginal benefits to pay a single landowner for producing ES are also rather small and the marginal costs of losing a single woodland may be so, too. However, cumulatively, the benefits of ES provided by woodland are vast but the transaction costs for each individual to pay each landowner for the ES provided by woodland would be extraordinary – especially when we think about global public goods such as climate regulation. There is also a lack of institutions that can facilitate payments from the beneficiaries of public good ES (society) to the providers of these (the landowner). This leads to a general under-provision with public good ES (see also NCC, 2013).

1.4.3 Externalities

A closely related market failure is that of externalities. Externalities (or external effects) describe a situation where a party is affected by an activity or transaction of another party (or parties) without choosing to be affected; and without compensation for the effect.

Externalities can be positive or negative and lead to both, suboptimal prices and the under-provision or overexploitation of goods and services such as many ES.

An example of a negative externality is air pollution. Let's say party A (for example an individual) buys a product such as a tablet from party B (a factory-owner producing tablets). This transaction includes producing and then transporting the product from party B to party A. Both, the production and the transport of the tablet cause air pollution which also affects party C (society). The transaction between party A and party B is deliberate as both parties agree to the transaction hoping to benefit from it – party A because it receives the product it desires and party B because it is compensated for the production and transport of the product via the agreed price party A pays. However, the effect on party C (poorer health due to the incurred air pollution (see for example Defra, 2017; Jones et al., 2017)) is not deliberate. Party C also cannot prevent party A and party B from making this transaction. Hence, a cost (poorer health) is incurred by party C for which it is not compensated for by either party A or party B.

Because this cost (the social cost of air pollution) is not factored in into the price party A pays party B for the transaction, the market price for the transaction does not reflect the costs incurred to party C. From a societal point of view, the price of transactions that incur air pollution (or any negative externalities) is therefore below the optimum because it does not reflect the 'true' costs as it does not include external (social) costs. Ideally, party C should be compensated for the negative externality by party A and/or party B. This would result in a higher price for the transaction leading to lower demand for goods incurring air pollution and negative externalities in general. This in turn would reduce overall air pollution to a level where the marginal costs (poorer health) do not exceed the marginal benefits (the production of goods and services that incur air pollution). Hence, negative externalities lead to both, prices below the optimum and social costs above the optimum. The internalisation of externalities does not completely avoid social costs such as through poorer health outcomes because of air pollution. However, it brings it down to an acceptable level (as all affected parties agree to the transaction (including the amount of the compensation)).

An example of a positive externality is air quality regulation. In this example party A (an individual) buys timber from party B (a forester). Party B plants and manages woodland to supply party A with timber. But the woodland does not only produce timber but also improves air quality. Party C (society) also benefits from these air quality regulation services. However, party C does not have to pay for this (ecosystem) service because it cannot be excluded from benefiting from it as clean air is a public good. Whilst party C can benefit as 'free-rider', it has no incentive to pay for the positive externality (air quality regulation). This means that the forester is not compensated (paid) for providing air quality regulation (or any other positive external effects including flood-, water quality- and climate regulation) which leads to a general under-provision of woodlands below the optimum for society. In an unregulated market, this applies to all NC assets that provide positive external effects.

1.4.4 Regulation Instruments and the Role of Valuation

Because the unregulated market often fails in circumstances where NC and ES are affected, arguably it needs to be regulated through regulations imposed and enforced by Government institutions. The regulatory instruments available can be broadly divided into non-market and market.

Non-market instruments include, for example, bans of particularly damaging substances such as ozone-depleting compounds (e.g. Chlorofluorocarbons; CFCs) and limiting deleterious impacts, such as pollution levels in vehicles (e.g. UK road tax bands). Government institutions may also choose to invest directly to provide public good ES such as through the creation and management of NC assets. Advantages of non-market instruments are that they are comparatively easy to understand, enforce and operationalise. The disadvantage is that they are usually not market-efficient:

> *"…the basic requirement for economic efficiency is that marginal costs equal marginal benefits, at both the individual level and the social level. Ideally, environmental policies should achieve this goal. In practice, however, for our pollution example this would require that we know the marginal social costs of pollution, the marginal net benefits of activities that pollute, and the marginal abatement costs*[5] *of pollution… In reality, it is virtually impossible to know all the*

[5] Abatement costs are the costs implementing e.g. new technologies to reduce pollution.

> *marginal costs of pollution and very difficult for policy makers to know marginal abatement costs."* (Daly and Farley, 2011, p. 428)

This illustrates both, the difficulty of defining efficient limits but also the importance of valuation to inform such decisions. Another problem is that defining limits does not provide incentives for improvements beyond the set limit.

A market option seems to be the allocation of property rights. An example is a factory that pollutes a river which affects a fisherman downstream because the pollution reduces the fish population. If the property rights of the river were allocated to the fisherman, the factory owner would have to compensate the fisherman for the pollution. If the property rights were allocated to the factory owner, the fisherman would have to pay the factory owner for cleaner water. Referring to Coase (1960), in terms of market efficiency it does not matter to whom the property rights are allocated as long as they are clearly defined and enforceable. In this case the market forces (negotiations between the factory owner and the fisherman) would lead to a market equilibrium without further Government intervention. However, this applies only under the assumption of no transaction costs which could maybe be manageable for this simple example but would be excessive for air pollution, for example, because a vast number of parties would be affected and would need to engage in negotiations. Property rights can also be difficult to enforce, especially when public goods span across several sovereign territories such as the case for air quality or climate regulation.

A related market instrument is price regulation such as through environmental taxes or subsidies where the property rights for the environment are effectively allocated to the Government. So called Pigouvian Taxes (Pigou, 1962, 1920) can be imposed on polluters to internalise externalities – ideally equal to the marginal external costs which would lead to a situation where marginal social costs equal marginal social benefits. This should adjust the price upwards and lead to a reduction of the pollution. In the case of the factory owner, if taxes are levied for the pollution, an incentive exists to reduce the pollution as a consequence. The tax may for example incentivise a reduction in production or the installation of advanced filter techniques. On the other hand, subsidies could be paid to landowners for managing the land as woodland to produce public good ES rather than managing it as intensively agricultural land. In both cases, the regulator would need to know the value of the non-market costs and benefits to set the tax or subsidy at the optimal level. A problem is that marginal costs change over time depending on supply and demand. Hence the tax would need to be adjusted accordingly.

A third market instrument is cap and trade. In this case a quota is set for the maximum pollution or resource depletion. Hence, this instrument does not directly affect the price but the total quantity of externalities such as air pollution. Market participants can then trade pollution rights so that the reduction can take place where it is most efficient to achieve. If a factory has high abatement costs making pollution reductions expensive, it may choose to buy pollution rights instead. But for another factory the abatement costs may be low. It is rationale for that factory to invest in advanced filter techniques and sell the pollution rights it does not need anymore.

Cap and trade makes the externality effectively a market good. It creates excludability to an otherwise nonexcludable good. This instrument is used in the European Union to trade carbon emission rights, for example. This instrument requires to estimate the efficient amount which should be defined based on biophysical constraints. Harvesting quotas such as for fishing rights should be set at the level where the stock can still renew itself and pollution caps at a level that does not exceed the waste absorption capacity of the environment. But even if pollution levels are below this level, they may still harm human wellbeing (Daly and Farley, 2011). Also, defining the efficient amount of pollution is not an easy task. It is arguable that in many cases some kind of valuation of the social costs is beneficial to define the optimal cap.

All these instruments have imperfections as well as advantages and there is no ‘magic bullet’ instrument to solve all environmental problems. Crucially, in all cases a good understanding of the value of open access regimes, public goods and externalities is required to implement these instruments efficiently.

> *“Failure to include the valuation of non-market goods in decision making results in a less efficient resource allocation, with negative consequences for social wellbeing.”* (UK NEA, 2011b, p. 13)

This includes the valuation of NC and the ES it provides and leads to the question how valuation can be operationalised.

1.5 Valuation Tools[6]

Decisions are generally conceived of as choices and trade-offs between competing alternatives across environmental, social and economic priorities. Such choices often require some form of valuation to reveal the relative weights given to aspects of a decision. One of the main aims of valuing ES is to make the overlooked and 'hidden' values of nature explicit (Daily et al., 2009). It is thus argued that valuing non-market ES leads to better informed and more rational decision-making (Bastian et al., 2012). However, decisions are not made by ecological experts; therefore it is important that decision-makers have tools that can be understood, used, applied and communicated within transparent decision-making processes (Fisher et al., 2009).

1.5.1 Valuing Environmental Goods and Services

The literature on valuing non-market goods and services has grown exponentially, fuelled by the advent of ES (Atkinson et al., 2012). Scientists have developed a set of valuation tools and methods to value non-market ES in monetary terms (Costanza et al., 1997; TEEB, 2010a). Whilst earlier attempts to value ES focused on the 'total value', more recent developments value the marginal changes in the provision of ES (UK NEA, 2011a). Utilising the total value of ES promotes the services and benefits ecosystems provide to human wellbeing to a broader audience (Fisher et al., 2009). However, valuing marginal changes, depending on the management of ecosystems, is thought to be superior for decision-making (Defra, 2007). The UK National Ecosystem Assessment (2011a) highlighted choices between options, with values assessed in the dimensions of relative costs and benefits of marginal changes in the provision of ES. Methods now exist that can unite natural sciences with economic assessment to estimate the relative value of changes under different scenarios and which thereby inform decision-making.

[6] The content of this Section (incl sub-sections) was previously published as Section 10.6.7 of a peer-reviewed research report: Scott, A., Carter, C., Hölzinger, O., Everard, M., Raffaelli, D., Hardman, M., Baker, J., Glass, R., Grayson, N., Harris, J., Taft, A., 2014. UK National Ecosystem Assessment Follow-on. Work Package Report 10: Tools – Applications, Benefits and Linkages for Ecosystem Science (TABLES). UNEP - WCMC, LWEC, UK. Hölzinger lead on this section of the NEAFO report. Other authors provided minor and/or editorial contributions to this section. Please note that the content of this Section reflects the state of the art at the time of the publication date (2014). Given that the work is already published in a peer-reviewed publication I did not attempt to update it again for inclusion in this thesis.

Another recent development is the shift from methods based on aggregated individual preferences to shared social values and principles of deliberative democracy. This includes value domains like fairness, social equity and sustainability (Hermann, 2011; Kenter et al., 2014). Furthermore, valuation focuses more on the valuation of 'final ES' which can directly be 'consumed' by humans rather than ecological processes benefiting or underpinning other ES, such as supporting services like soil formation (Atkinson et al., 2012). Distinguishing between 'final' and 'intermediate' ES is important to avoid double-counting when valuing.

1.5.2 Dimensions of Valuation Tools and their Application

Monetary valuation tools reveal values given in financial currency; non-monetary valuation tools reveal values qualitatively or as 'weightings'. The main advantage of monetary valuation is that outcomes are given in a common metric which allows the user to derive 'net' benefits and costs (Fisher et al., 2011). However, monetary valuation is complex and demands robust primary valuation studies that cover ES relevant to the decision-context. Conducting such studies can be very expensive and riddled with uncertainty and knowledge gaps. Importantly, not all ES and their attributes can be valued in monetary terms particularly cultural ES and non-use values (Atkinson et al., 2012).

Thus, applying monetary valuation methods exclusively exposes an inherent risk that the results hide more than they reveal giving a false sense of certainty. Monetary valuation using contingent valuation is restricted to relatively simple scenarios that are conceptually manageable for participants. This makes it extremely challenging to incorporate risk, uncertainty and complexity. In addition, it is often unclear exactly how changes in ecosystems lead to changes in final benefits. In the case of cultural services, it is also problematic to conceptualise 'subtle' cultural benefits of settings such as sense of place in a way that fits a monetary valuation framework (Church et al., 2014). Furthermore, it may not always be appropriate or desirable to place monetary values on ES; for example in cases where no acceptable substitute exists without causing significant biodiversity loss (Turner et al., 2003). Therefore, non-monetary valuation or the combination of monetary and non-monetary valuation tools can be highly beneficial.

One option for non-monetary valuation is to collect relevant information from the literature. However, such information for a specific decision context is not always available. An alternative is to base values on expert judgement. Experts can, for example, ascertain 'weightings' to specific ES based on their knowledge and experience. Alternatively, values can be elicited from focus groups or citizens' juries. The latter technique is designed to obtain public opinion on different policy options and their impacts on society, usually informed by experts or relevant evidence (Spash, 2007). As a general rule a critical interpretation of findings should be mandatory whenever valuation tools are applied.

1.5.3 Monetary Valuation Tools: Primary Valuation Stage

As a general rule, valuation tools essentially only help provide an approximation of the 'real' value, though Helm and Hepburn (2012, p. 17), for example, argue that *"it is better to be approximately right, than precisely wrong"*. If ES are traded in markets the value can often be derived from (adjusted) market prices. However, many ES are not traded in markets as they occur as externalities. A party might for example benefit from water quality improvements upstream without paying for such improvements. In such cases the market price does not reflect the full benefits (costs) of a transaction. Sometimes it is possible to derive such values indirectly from market prices. Applying the revealed preferences method, one derives the ES value from market goods and services which contain environmental attributes (Defra, 2007). One example is the hedonic pricing method where differences in property prices dependent on environmental surroundings are used as indicators for the value of such externalities. So, for example, living adjacent to a green space or park leads to higher prices (UK NEA, 2011a). Stated preference techniques, on the other hand, elicit the value of ES by asking people their willingness-to-pay (WTP) or willingness to accept (WTA), in terms of non-substitutability of certain areas, habitats or provisions, for ES if there were a market. The latter technique can be applied to a wide range of ES including cultural and intangible ones. Such techniques have attracted significant criticism, however, leading to over valuation (Kenter et al., 2014).

An emerging tool is Deliberative Monetary Valuation (DMV) (Niemeyer and Spash, 2001). This encapsulates a wide range of approaches incorporating participatory, deliberative and/or social learning processes, to establish a monetary value for the benefits of environmental goods. In DMV, small groups of participants explore the values that should guide their group decisions through a process of reasoned discourse (Howarth and Wilson, 2006). DMV addresses the critique of contingent valuation that they do not assess risk and uncertainty and capture the intricacies of human values and that values cannot be assumed to be pre-formed (Kenter et al., 2011).

1.5.4 Benefit Transfer

Applying primary valuation tools is usually comparatively cost-intensive which limits their efficient applicability, especially to support 'everyday' decisions (Defra, 2007). The benefit transfer approach offers an alternative by transferring values from primary valuation studies ('study site') to the relevant decision-making context ('policy site'). The application of the benefit transfer approach can be seen as a practicable and cost-effective way to implement the ES Framework in decision-making, even if the accuracy of the outcomes declines (Hermann, 2011). It is also recommended by Defra (2007) for making more practical use of environmental values in policy-making. However, if not applied appropriately the outcomes can be strongly biased, leading to poor decisions (Bateman et al., 2011; Spash and Vatn, 2006).

1.5.5 Valuation Tools: Operational Stage

Cost Benefit Analysis (CBA) is a popular tool involving a systematic process where expected costs and benefits of a project or policy are compared. It can be used to determine if an investment is efficient; or to compare different investments to identify the most efficient application of funds. For the latter case also the related Cost-Effectiveness Analysis (CEA) might be applied. Here the question to solve is how an intended outcome can be achieved for the lowest costs rather than 'policy on or off'. For both tools monetary valuation is necessary which means that some ES usually remain undervalued or ignored. Another unresolved problem centres on how equity (current and intergenerational) issues can be better integrated (Sáez and Requena, 2007). Therefore, outcomes must be interpreted carefully.

Social Return On Investment (SROI) builds upon the principles of CBA but optimises social and environmental impacts through the involvement of stakeholders who determine which impacts of a decision should be valued and then apportion monetary 'proxy-values' to such impacts.[7] SROI may therefore be able to incorporate a broader set of non-market values but the accuracy of such proxy-values is usually less precise.

For more complex problems or if relevant monetary valuation evidence is unavailable, Multi-Criteria Decision Analysis (MCDA) is used. MCDA is a structural approach that explicitly considers, integrates and evaluates multiple and heterogeneous dimensions and criteria. One main advance of this technique is that it prevents the loss of important information throughout the decision-making process (Kiker et al., 2005). MCDA allows, for example, to integrate information from other tools such as CBA (Barfod et al., 2011), or valuation evidence can be evaluated directly. It commonly assigns 'scores' or 'weightings' to different attributes and impacts of policy options to make them comparable across diverse indicators, metrics, and stakeholder groups.

Corporate Ecosystem Valuation (CEV) is a tool devised by the World Business Council for Sustainable Development (WBCSD, 2011). CEV serves corporate decision-making by identifying and valuing ecosystem impacts by businesses; but also risks and opportunities businesses face from changing ES. It aims to improve corporate performance including social and environmental goals. In general, CEV can be applied to a business as a whole, but also products, services, projects, assets, or an incident. CEV is flexible and allows incorporating monetary and nonmonetary valuation as well as different tools outlined above. However, such high flexibility also contains the danger that the tools may be used inappropriately, e.g. for 'green washing'.

1.5.6 Discounting

Because the costs and benefits of decisions affecting ecologies often occur in the remote future it is common to calculate their 'net present value'. Usually a discount rate is applied to convert future costs and benefits to a present-day equivalent to make them comparable. HM Treasury recommends applying a discount rate of 3.5% for periods of up to 30 years. Afterwards the discount rate declines stepwise to 2.5% (HM Treasury, 2003). However, consensus does not exist about the level of the discount rate and it is controversial (e.g.

[7] SROI does not necessarily require monetary valuation; the application of quantitative 'weightings' or 'scores' might also be appropriate.

Bingham et al., 1995; German Federal Environment Agency, 2008; Perino et al., 2011; Sáez and Requena, 2007; Stern, 2006). In particular, applying the 'pure time preference rate' for decisions with inter-generational effects potentially clashes with intergenerational equity issues.

The outcome of many valuation tools is sensitive to the applied discount rate. Decisions affecting ecosystems often have intergenerational effects and applying a high discount rate gives benefits and costs occurring in the remote future a very low (often negligible) weight (Atkinson and Mourato, 2008). The German Federal Environment Agency (2008) recommends using a discount rate of 1.5% for periods of more than 20 years with a sensitivity of 0% to account for cross-generational considerations. If the discount rate recommended by HM Treasury is applied, £1000 now is taken into account with £197 in 50 years. However, applying a discount rate of 1.5% would result in £475. Consequently, an open discussion and potentially a revision of the discount rates recommended by HM Treasury would seem to be a legitimate subject of debate.

1.5.7 Summary

There is no 'one size fits all' valuation tool. The selection of tools to support decision-making is strongly dependent on the policy context and issues like scale, scope, complexity, budget and time restrictions all affect this. In addition, the knowledge level and expertise of the valuer and decisionmaker have significant effects on the outcome. Many valuation tools are still under development and divergent applications as well as hybrid forms such as 'social multi-criteria evaluation' or 'deliberative mapping' are evolving. This makes the selection of valuation tools both complex and a crucial element of any decision-making process. To ensure that the application of valuation tools provides robust and reliable outcomes it should be mandatory that tools are not just applied by experts, but also well written up and reported, including a critical and transparent interpretation covering limitations and caveats which apply to all valuation tools. Here the definition of minimum quality standards or a mandatory review process may be beneficial.

If we want to improve decisions by making better use of valuation tools, we also have to apply such tools to more relevant decision-making contexts. To date, valuation tools are almost exclusively used to inform (micro-economic) project level decisions. The influence on macro-economic, local economic strategic planning, or spatial planning is extremely limited (Anger et al., 2014). The same applies for corporate decision-making as a whole. However, to implement such tools within the broad range of (everyday) decisions affecting ES, it is not just necessary to ensure that the relevant evidence is available and that such tools are applied appropriately; it will also be necessary to change the institutional setup to enhance or make the application of valuation tools compulsory for such decisions.

1.6 Valuation Tools and Decision- and Policy Making

The concepts and valuation of NC and ES have been recognised to have great potentials to inform decision-making for some time now; allowing more rationale and better informed decisions affecting the environment (Bastian et al., 2012; Bingham et al., 1995; Fisher et al., 2009; Lundy and Wade, 2011; Turner and Daily, 2008; Wainger et al., 2010). However, it is also recognised that these concepts have played a comparatively small role in real-world decision-making in the past (Daily et al., 2009; Daily and Matson, 2008; Kroll et al., 2012; Laurans and Mermet, 2014; Layke, 2009; Primmer and Furman, 2012; Shi, 2004) although more and more examples emerge where these concepts have been used to inform decisions (Galler et al., 2016; Hedden-Dunkhorst et al., 2015; McKenzie et al., 2014; Ruijs and van Egmond, 2017; Schaefer et al., 2015). In the UK, commitment to implementing these concepts are clearly evidenced through policy and guidance documents (Defra, 2007; HM Government, 2018, 2017, 2011; HM Treasury, 2018; NCC, 2017, 2013).

In this section (1.6) I outline a general decision-making framework within which NC and ES valuation tools can be contextualised (Chapter 6). I also review UK planning policy with respect to NC and ES valuation (Chapter 5). Furthermore, I briefly outline different spatial levels within which NC and ES valuation tools are applicable.

1.6.1 The Policy- and Decision-making Process

Here, I analyse a typical policy- and decision-making cycle for the UK given that my case study Birmingham is located in the UK. In the UK Government's guidance on appraisals and evaluation, the 'Green Book', the ROAMEF (Rationale, Objectives, Appraisal, Monitoring, Evaluation and Feedback) policy cycle is embedded (HM Treasury, 2018, 2003). This policy cycle, which is also implemented in many Government departments including Defra, is presented as a rational and controllable process where a policy is produced that meets a clear goal (Scott et al., 2014).

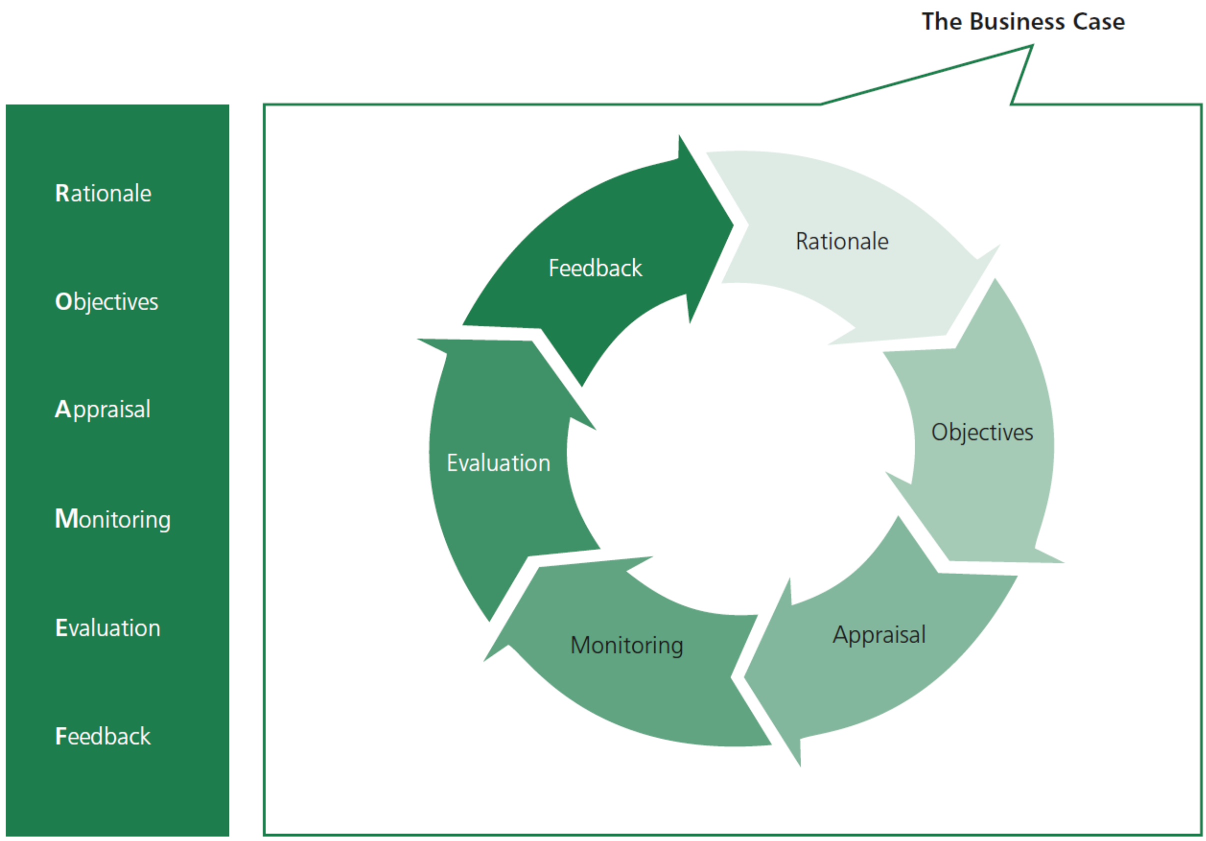


Figure 1.4 The ROAMEF Policy Cycle used in UK Policy Appraisals. The figure illustrates an idealised policy cycle UK decision-making should follow. The cycle starts with (1) a rationale for a policy intervention; subsequently followed by (2) defining clear objectives of an intervention; (3) appraisals of policy options such as through Cost Benefit Analysis; (4) monitoring of the baseline and impacts of the intervention; (5) an evaluation of the policy at different stages of the intervention; and (6) feedback such as 'lessons learnt' which can inform the next policy cycle. *Source: HM Treasury (2018, p. 9)*

Based on the ROAMEF policy cycle, Scott et al. (2014) developed an adapted IDEAS-SURVEY-ASSESS-PLAN-DELIVER-EVALUATE policy cycle as part of Work Package 10 of the UK National Ecosystem Assessment Follow-On (UK NEAFO) research project: Tools – Applications, Benefits and Linkages for Ecosystem Science (TABLES). This adapted cycle also includes IDEAS and DELIVERY stages. Because this cycle has been developed to contextualise decision-support tools adopting (or adopted for) the principles of the Ecosystem Approach (Scott et al., 2014), it is highly relevant in the context of this investigation.

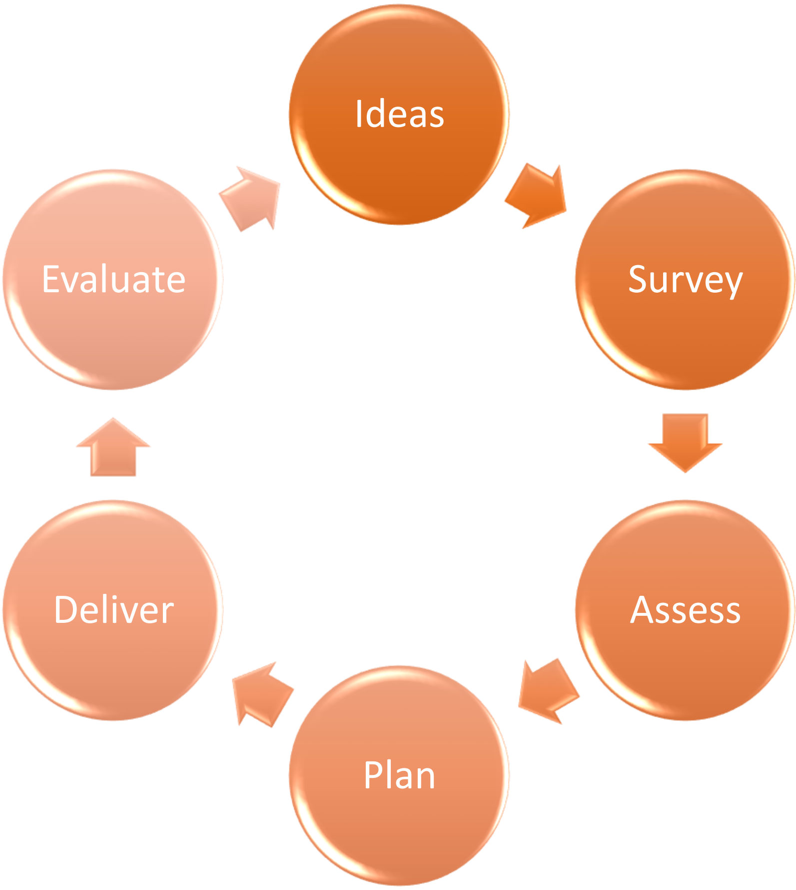


Figure 1.5 The UK NEAFO Policy Cycle. The figure illustrates an idealised policy cycle used as part of WP 10 of the UK NEA which includes 6 subsequent stages. *Source: Based on Scott et al., (2014).*

The Ecosystem Approach follows 12 principles[8] and can be defined as:

> *"a strategy for the integrated management of land, water and living resources that promotes nature conservation and sustainable use in an equitable way*

[8] 1. The objectives of management of land, water and living resources are a matter of societal choices; 2. Management should be decentralized to the lowest appropriate level; 3. Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems; 4. Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context; 5. Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach; 6. Ecosystem must be managed within the limits of their functioning; 7. The ecosystem approach should be undertaken at the appropriate spatial and temporal scales; 8. Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term; 9. Management must recognize the change is inevitable; 10. The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity; 11. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices; and 12. The ecosystem approach should involve all relevant sectors of society and scientific disciplines. (https://www.cbd.int/ecosystem/principles.shtml; accessed: 2nd December 2019)

recognising that humans with their cultural diversity are an integral part of ecosystems" (Convention on Biological Diversity, COP 7 Decision VII/11)

Notably, principle 4 of the Ecosystem Approach states:

"Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:

1. *Reduce those market distortions that adversely affect biological diversity;*
2. *Align incentives to promote biodiversity conservation and sustainable use;*
3. *Internalize costs and benefits in the given ecosystem to the extent feasible.*

The greatest threat to biological diversity lies in its replacement by alternative systems of land use. This often arises through market distortions, which undervalue natural systems and populations and provide perverse incentives and subsidies to favor the conversion of land to less diverse systems.

Often those who benefit from conservation do not pay the costs associated with conservation and, similarly, those who generate environmental costs (e.g. pollution) escape responsibility. Alignment of incentives allows those who control the resource to benefit and ensures that those who generate environmental costs will pay."[9]

Arguably, (better) valuation of NC and ES, as through valuation tools, is fundamental to the implementation of this goal which is why I adopt it for the contextualisation of valuation tools within this investigation. The subsequent steps of the IDEAS-SURVEY-ASSESS-PLAN-DELIVER-EVALUATE policy cycle are further detailed here based on Scott et al. (2014)[10]:

<u>Ideas</u>

Every policy, plan, project or programme (PPPP) starts with ideas. Ideas may for example be triggered or required because of new challenges such as climate change but also because of new opportunities such as arising from technological progress or new research. Ideas can also

[9] https://www.cbd.int/ecosystem/principles.shtml; accessed: 2nd December 2019
[10] Also http://neat.ecosystemsknowledge.net/; accessed: 3rd December 2019

be the result of lessons learnt from former/other PPPPs. In any case it is advised to identify and work with stakeholders who are either affected by and/or engaged with a resulting PPPP. In practice, the initial ideas stage is likely to have the least resources allocated despite their great importance for producing optimal outcomes. Ideas should consider PPPP aims and objectives, previous work and lessons learnt, the spatial/political boundaries of the PPPP, the distribution of intended outcomes, and resource requirements.

Survey

The purpose of the survey phase is to collect initial evidence to inform the potential options identified as part of the ideas stage. Deciding on a PPPP option without reviewing the evidence may result in unexpected or even unintended/perverse outcomes further down the line. If serious data gaps are identified as part of the survey stage then new data collection should be considered if this can be done within reasonable timescales (especially for solving urgent problems). This will also be determined by the availability of resources. In relation to NC and ES, the survey phase should ideally include the establishment of a robust baseline assessment. Questions to consider for this stage are the survey scope, data availability, requirements and gaps, and key lessons emerging thus far.

Assess

At this stage the data and evidence collected during the survey stage is assessed. Here, it is important to transparently and explicitly outline any evidence gaps and assumptions. It is also advised to assess all policy options which emerged from the ideas stage to ensure a fair and transparent process. Importantly, all relevant evidence should be assessed rather than limiting oneself to evidence that may favour pre-favoured options or solutions. Questions to consider include how conflicting positions and trade-offs should be managed, on which basis a decision for a preferred option should be made, and if the process would benefit from involving stakeholders. The result of an assessment is usually a preferred option to be taken forward.

Plan

Good and detailed planning will enhance the chances that a PPPP can be successfully delivered. Any plan should be SMART (specific, measurable, attainable, relevant and time-bound). Founded in the initial aims and objectives, the plan outlines a clear set of actions to be undertaken for the delivery of the PPPP. It is advised to involve both, stakeholders and those delivering the PPPP to mitigate later opposition and rejection. The plan should identify individuals and institutions to deliver key actions and set clearly defined timescales and milestones.

Deliver

The purpose of the delivery stage is to implement the preferred PPPP. The effective communication of the plan to those charged with the delivery is crucial here. It is also important that the plan is accepted and supported by those delivering it. Otherwise those delivering the PPPP may derail from the plan and proceed with 'business as usual' practice. Depending on the quality of the plan, but also the complexity of the PPPP, adjustments may be required. It is advisable to record and share the lessons learnt from difficulties encountered during the delivery of a PPPP to enable better (adapted) planning in the future.

Evaluate

The evaluation phase services to determine the success of a PPPP. Evaluation should not be seen as the last stage of the PPPP or simply an add-on. It should be understood as an integral part of the process. Hence, evaluation is relevant not only after the PPPP is delivered but also throughout the process – such as for important milestones as defined during the planning stage. Any PPPP should be evaluated against its initially agreed aims and objectives. With respect to NC and ES, indicators should have been defined at the ideas stage that allow the objective assessment of success against the NC/ES baseline developed during the assessment stage. Questions to consider during the evaluation stage include whether and to what extent aims and objectives are being met, to what extent stakeholder needs are satisfied, and which lessons can be learnt to improve the actual and/or future PPPPs.

Given (1) that IDEAS-SURVEY-ASSESS-PLAN-DELIVER-EVALUATE represents a generic and conventional policy cycle model adapted from the ROAMEF model which is embedded in many UK Government Departments; (2) that it has already been used to assess and contextualise (valuation) tools as part of the UK NEAFO; (3) the links between NC, ES and the Ecosystem Approach; and (4) that the NC/ES valuation helps to mitigate undervaluation of NC and ES (Millennium Ecosystem Assessment, 2005; UK NEA, 2011b) which is fundamental to achieving goal 4 of the Ecosystem Approach; it was sensible to adopt this policy cycle to contextualise NC and ES valuation tools as part of this investigation in Chapter 6.

Notwithstanding that the IDEAS-SURVEY-ASSESS-PLAN-DELIVER-EVALUATE policy cycle provides a valuable model for contextualising NC and ES valuation tools, it needs to be recognised that it is a theoretical model. Gaps between idealised models of policy-cycles and 'real-world' decision-making can be identified by both, practitioners and academia (Institute for Government, 2011). In reality, *"policy-making is necessarily a messy and complex process and thus there is considerable challenge in trying to develop models that adequately capture this."* (Scott et al., 2014, p. 38). Whilst this policy-cycle is grounded in UK policy, which is sensible given that my case study is located in the UK, the cycle is also applicable beyond the UK context.

1.6.2 UK Planning Policy Review

Land-use change due to development is one of the main drivers of NC and ES degradation (Bastian et al., 2012; Dallimer et al., 2011; IPBES, 2018; United Nations, 2013). Balancing the needs for engineered infrastructure such as housing and transport networks with green infrastructure remains a major strategic planning challenge (HM Government, 2011; RTPI, 2015). Planning practitioners face diverse and often competing demands such as economic growth, the need for (affordable) housing, biodiversity and climate change (Mell, 2014; Scott and Hislop, 2019; Wilker et al., 2016). In its Natural Environment White Paper, the Government acknowledges that the UK planning system is not fit for purpose to deliver sustainable land-use:

> *"Planning has a key role in securing a sustainable future. However, the current system […] is failing to achieve the kind of integrated and informed decision-making that is needed to support sustainable land-use."*
> (HM Government, 2011, p. 21).

Whilst information about the impact of new development on NC and ES is usually not systematically assessed in the planning context (de Groot et al., 2010), the consideration of NC and ES value in the English planning system is slowly emerging (HM Government, 2018, 2011; MHCLG, 2018; Smith et al., 2018).

Given that one of the tools assessed as part of this investigation, namely the Natural Capital Planning Tool (NCPT; see Chapter 5) is specifically designed to assess NC and ES in the English planning and development context, it is useful to get a better understanding of how NC and ES are dealt with in English planning policy. Here, I provide a brief review of some key policies with respect to how ES and NC are managed in the English planning context.

Within the English planning system there are two key resources: the National Planning Policy Framework (NPPF; MHCLG, 2018) and the accompanying National Planning Practice Guidance (NPPG; MHCLG, 2019). This review also includes the recent key Government policy with respect to the natural environment; namely the 25 Year Environment Plan (25 YEP; HM Government, 2018).

<u>25 Year Environment Plan (25 YEP)</u>

The 25 YEP (HM Government, 2018) articulates the ambition *"to leave our environment in a better state than we found it."* (p. 6). Numerous explicit and implicit references to NC and ES are made throughout the 25 YEP which evidences that the concepts and their terminology start to transcend into Government policy. Given that this document is an HM Government publication, in principle all government departments (should) have signed up to it.

With specific reference to planning policy, the Government pledges *"to put the environment at the heart of planning and development to create better places for people to live and work."* (p. 32). The threats to greenspaces and green infrastructure as well as the requirement to create more greenspaces to enhance benefits from ES is also acknowledged:

> *"Green infrastructure brings wider benefits, including sequestering carbon, absorbing noise, cleansing pollutants, absorbing surface water and reducing high temperatures. The number and condition of green spaces has declined and current investment is confined to specific projects. We risk losing more good quality green spaces. As we build more homes, preserving and creating green spaces in towns is more important than ever. Local authorities and developers need to take account of all the benefits when deciding how much land to allocate as green space."*
> (p. 79).

The 25 YEP also states that the Government *"will seek to embed a 'net environmental gain' principle for development to deliver environmental improvements locally and nationally."* (p. 33). It will consult on mandating 'environmental net-gains' including NC benefits in the planning system which is encouraging. Specific actions of the 25 YEP with respect to how NC and ES are managed in the planning system include (p. 34):

- *"Working with interested parties to reduce costs to developers by expanding the net gain approaches used for wildlife to also include wider natural capital benefits such as flood protection, recreation and improved water and air quality - streamlining environmental process, whilst achieving net environmental gains.*
- *Working with interested parties to improve and expand the range of tools and guidance that support biodiversity net gain approaches, including through the future incorporation of natural capital measures.*
- *Exploring, through ongoing MHCLG-led reforms of developer contributions, how tariffs could be used to steer development towards the least environmentally damaging areas and to secure investment in natural capital."*

Notably, the Government has announced in its Spring Statement 2019 to mandate biodiversity net-gain in the future[11] and is developing and testing a new tool, the eco-metric, which assesses and quantifies the impact of land-use change on ES; aimed at operationalising environmental net-gains in the planning system (Smith et al., 2018).

Overall, the high-level policies and goals as articulated in the 25 YEP are ambitious and encouraging. But it should also be recognised that these ambitious high-level policies are somewhat watered-down when looking at the more practice-relevant policies of the NPPF and NPPG; at least at this stage.

[11] https://www.gov.uk/government/news/spring-statement-2019-what-you-need-to-know (accessed: 07/12/2019)

National Planning Policy Framework (NPPF) (MHCLG, 2018)

The NPPF sets out the government's planning policies for England and how these are expected to be applied. Notably, the terms 'natural capital' and 'ecosystem services' are explicitly mentioned three times in the NPPF:

> *"Planning policies and decisions **should** contribute to and enhance the natural and local environment by […] **recognising** the intrinsic character and beauty of the countryside, and the wider benefits from natural capital and ecosystem services – including the economic and other benefits of the best and most versatile agricultural land, and of trees and woodland"* (par. 170).

> *"Plans **should** […] allocate land with the least environmental or amenity value, where consistent with other policies in this Framework; take a strategic approach to maintaining and enhancing networks of habitats and green infrastructure; and plan for the enhancement of natural capital at a catchment or landscape scale across local authority boundaries."* (par. 171).

The fact that NC and ES are not used more frequently indicates that there is no strong emphasis on such issues. It should also be recognised that the policy wording in these instances is rather weak evidenced by the use of words like 'should' or 'recognising' rather than 'must' or 'assess'. This also means that there is no statutory requirement to do so. But it still provides an important opportunity space for policy development (see also Scott et al., 2017) and is an improvement to the previous NPPF (DCLG, 2012) where ES were mentioned only once and NC not at all.

It should also be noted that NC and ES is implicitly mentioned in other areas such as in paragraph 72 where it states that *"strategic policy-making authorities should […] consider the opportunities presented by existing or planned investment in infrastructure, the area's economic potential and the scope for net environmental gains"* or paragraph 93: *"Planning policies and decisions should consider the social, economic and environmental benefits of estate regeneration."* But the overall problem of weak policy wording remains.

National Planning Practice Guidance (NPPG)

The NPPG[12] is a web-based portal that essentially translates the NPPF into priorities on the ground with respect to day to day practices of policy/plan development and decisions and puts 'flesh on the bones' of the NPPF (Scott et al., 2017). Here, NC and ES are only explicitly mentioned within the Green Belts and the Natural Environment sections.

In the Green Belt section of the NPPG, compensatory measures for necessary development on the Green Belt **should** be set out in policies which **could** include *"improvements to biodiversity, habitat connectivity and natural capital"* (par. 2). To ensure that compensatory improvements will be secured, such as through the Community Infrastructure Levy[13], **consideration will need to be given** to *"the scope of works that would be needed to implement the identified improvements, such as new public rights of way, land remediation, natural capital enhancement or habitat creation and enhancement, and their implications for deliverability"* (par. 3).

In the Natural Environment section, NC and ES are mentioned 6 times such as with respect to soil safety and green infrastructure. It is encouraging that under the heading *"How **can** ecosystems services be taken into account in planning?"* (par. 17), specific guidance on ES is linked which also highlights methods of ES valuation.[14] Also notably, in paragraph 21, the guidance states that *"plans, and particularly those containing strategic policies, **can** be used to set out a suitable approach to both biodiversity and wider environmental net gain…"* which is further detailed in paragraph 28:

> *"The aim of wider environmental net gain is to reduce pressure on and achieve overall improvements in natural capital, ecosystem services and the benefits they deliver"* and that *"In planning strategically for the enhancement of natural capital, planning authorities **can** draw upon evidence on natural capital assets, the supply and demand of ecosystem services flowing from them, and existing and future risks and opportunities for these services."*

[12] The NPPG is updated more frequently than the NPPF. This review is for the NPPG as of 06/12/2019.
[13] The Community Infrastructure Levy (the 'levy') is a charge which can be levied by local authorities on new development in their area.
[14] https://www.gov.uk/guidance/ecosystems-services (accessed: 07/12/2019)

Whilst this is encouraging, the problem of comparatively weak policy wording remains also in the NPPG. This means that the incorporation of NC and ES into plan- and decision-making remains at the discretion of the local planning authority.

There are also a range of opportunities missed by for example not explicitly referring to NC and ES in guidance on ‘Environmental Impact Assessments’ and ‘Strategic environmental assessment and sustainability appraisal’. Furthermore, it is arguable that ‘Viability’ may not be restricted to economic viability, but could be extended to social and environmental viability. Disappointingly, green infrastructure is only accounted for as a cost factor here (par. 12) without specific reference to its social and environmental benefits such as through ES.

The emphasis on environmental net-gains within English planning policy is particularly encouraging. Arguably, assessing whether environmental (NC) net-gains will/has been achieved for a plan or development project requires some kind of valuation and quantification. Hence, the need for valuation tools such as the NCPT (Chapter 5) or the eco-metric (Smith et al., 2018). These valuation tools form part of a suit of NC and ES valuation tools – some of which have been used in Birmingham. The experiences from applying such valuation tools are outlined in the following chapters.

2 Chapter Two: Multiple Challenge Map for Birmingham – Ecosystem Services Supply and Demand Maps[15]

2.1 Abstract

In this Chapter I developed comprehensive ecosystem services (hereafter ESs) supply and demand maps for Birmingham with the specific purpose of informing land-use decisions. These maps were aggregated to a 'multi-layered challenge map' indicating areas that require ES enhancement as well as 'ES hotspots' which require additional protection, such as from development.

The maps were produced in partnership with stakeholder and expert groups. This helped to ensure that the evidence produced was grounded in local knowledge and 'fit-for-purpose' to inform land-use decisions affecting green infrastructure. A bespoke model was developed to ensure that the evidence provided can be easily utilised and implemented by land-use decision-makers. The whole approach was driven by the demand for better evidence at the city scale with respect to the supply and demand for ES.

2.2 Introduction

Academia as well as many policy agendas in the UK recommend and promote the ESs concept and its implementation in decision-making and planning (HM Government, 2018; MHCLG, 2018; NCC, 2015; Bastian et al., 2012; Burkhard et al., 2012; Kroll et al., 2012; HM Government, 2011; Daily et al., 2009; UK NEA, 2011a; Fisher et al., 2009; Defra, 2007).

An important element of the 'ESs toolbox' is ecosystem mapping. One advantage of mapping ESs is that it visualises and spatialises complex information and allows an easier uptake by decision-makers (Burkhard et al., 2012). Worldwide, more and more attempts have been made to spatially explicit map ESs. The numbers of academic case studies on urban ESs is

[15] The content of this Chapter was previously published as a research report which was published as Appendix 2 of Birmingham's Green Living Spaces Plan (Birmingham City Council, 2013): Hölzinger, O., Tringham, N., Grayson, N. & Coles, R., 2013. Birmingham Green Living Spaces Plan: Multiple Challenge Map for Birmingham - Ecosystem Services Supply and Demand Maps. Birmingham City Council, Birmingham. The content of this report was amended and updated to be suitable for inclusion in this thesis. The co-authors listed above provided editorial comments apart from Tringham who undertook the technical task of creating the maps with Geographic Information System (GIS) software. This was based on methods and data developed by Hölzinger.

growing exponentially (Luederitz et al., 2015). It needs to be recognised, however, that such research still only has a limited impact on real-world decision-making (Nahuelhual et al., 2015), even if the high demand for policy implementation of such approaches is widely accepted (Burkhard et al., 2012; Koschke et al., 2012; Scolozzi et al., 2012).

One reason is that such mapping exercises have often been undertaken at a broad scale and cannot be directly translated to the local level where most planning decisions take place (Burkhard et al., 2012; Haines-Young et al., 2012). Furthermore, research assessing the flow of ESs is rare even if its importance is recognised (Bagstad et al., 2012; Chan et al., 2006; Egoh et al., 2007; Fisher et al., 2011; Schröter et al., 2014; Syrbe and Walz, 2012). Most mapping exercises in the past have focused on the ecosystem function or potential to provide ESs rather than incorporating the demand side as well, even if this is seen as being of crucial importance (Burkhard et al., 2012; Kroll et al., 2012; Syrbe and Walz, 2012). Fisher et al. (2009, p. 646) provide a very tangible thought experiment to clarify this issue: Assuming there was an Earth-like planet with no humans, that planet would have a wide array of ecosystem structures, processes and functions. But because there is no human demand, there would be no ESs.

Another reason why ES mapping has not been sufficiently implemented into decision-making yet is arguably that mapping exercises often focus on single ES or small bundles of ES (Pulighe et al., 2016; Baró et al., 2015; Larondelle et al., 2014; Malczewski, 2006). This selection of assessed ES is often not based on the decision-making context and the information that would be most useful to decision-makers. One reason is that relevant information and data-availability is often lacking (Burkhard et al., 2009; Maes et al., 2012; Turner and Daily, 2008). However, if approaches to value and map ES are not driven by the demands of the decision-makers, it is not surprising that its implementation for decision-making purposes is unsatisfactory. It is arguable that the benefits for decision makers and planners are limited because they need to consider a wide range of indicators including a wide range of ESs relevant at the local (city) scale to inform their decisions (de Groot et al., 2010). Another barrier is that the complex ES concept and its terminology are often not entirely understood by their potential users in a decision-making context (Fish, 2011; Paetzold et al., 2010).

Demand-driven, spatial mapping of ESs has the potential to overcome these constrains because maps are easily accessible for a wider audience. The visualisation of ESs via maps can aggregate complex information which makes the concept more tangible for non-specialists (Burkhard et al., 2012). This is even more important when mapping a wider range of ESs as in the present study. Therefore, the present research can be considered as a practicable approach to aid decision-making affecting ecosystems 'on the ground'.

Nahuelhual et al. (2015) undertook a review of 50 ES mapping studies between 2005 and 2012 and identified a disconnect between the purpose of a study (for example to inform land-use planning) and the selected variables to inform the studies. Moreover, they identified that no reviewed study aimed at informing land-use planning involved stakeholders.

To provide maximum transparency and applicability, I decided to apply a decision-context driven 'bottom-up' approach when developing ESs supply and demand maps for Birmingham. This investigation was steered by what decision-makers and relevant stakeholders in Birmingham were asking for to help improve planning decisions. The study was funded by Birmingham City Council which indicates a direct demand. Stakeholders were involved in the process throughout all stages of the project, from design to delivery.

Applying a bottom-up approach may reveal one problem - decision-makers and practitioners may demand tools and information which academia cannot provide to a sufficient degree and accuracy (Burkhard et al., 2012). However, decisions affecting the environment often cannot wait for better scientific evidence evolving over time that may reduce uncertainty - they have to be made now. As a result, this study used proxies that are not based on perfect scientific evidence, but provide a real practicable decision-aid. It is crucial however, that all caveats and shortcomings of the approach and applied methods are made transparent.

This Chapter outlines the creation of a 'multiple challenge map' for Birmingham City Council. The purpose of the project was to evaluate the spatial supply of; and demand for important ESs at the city scale. The different supply-demand maps have then been aggregated to provide a 'blueprint' of Birmingham's spatial demand for additional green infrastructure to provide ESs where they are needed most.

The main aim of the project was to produce a set of maps which inform decisions affecting Birmingham's green infrastructure with respect to ESs impact. The objectives were: (1) to produce spatial maps identifying areas where the demand for ES cannot be sufficiently satisfied; and (2) to identify areas where ES 'hotspots' exist which are providing a very high value of benefits across a wide range of ESs.

The former indicates in which areas of Birmingham a specific need for the creation and/or enhancement of green infrastructure would be most effective. This allows for example to prioritise actions with respect to Nature Improvement Area (NIA) related projects. The latter indicates where existing green infrastructure is particularly valuable and does therefore require specific protection/measures – irrespective of formal habitat designations.

This chapter adds to the scientific literature by combining four important factors when mapping ESs: (1) being driven by the local decision-maker who requires the evidence, Birmingham City Council; (2) explicitly assessing not just the supply of but also demand for ESs; (3) explicitly considering the distribution of supply and demand for ESs in space; and (4) involving relevant stakeholders throughout all steps of the process.

2.3 Methodology

The approach used in this study should be seen as a pragmatic approach. It uses methodologies and evidence that were available at the time of the assessment and can be implemented for decision-making purposes; considering inherent time- and resource restrictions. Available scientific evidence has been accompanied by expert judgement to overcome the lack of data and sufficient indicators. Recognising such caveats, the approach will not provide decision-makers in Birmingham with perfect information; but with an information base that is a significant improvement on the status quo. Therefore, this approach should be interpreted as a stepping stone towards implementing the ESs concept in decision-making. Future research will advance improvements and refinements of this experimental approach.

2.3.1 Assessment Scope

Supply and demand of ESs can differ significantly over space and time. While recreational benefits are often demanded mainly locally, global climate regulation - mitigating the negative impacts of climate change - is demanded globally and over a long time period. Therefore it is crucial to clearly define the scope of an ES assessment in terms of space and time (Paetzold et al., 2010).

The context specific decision-making purpose of the investigation has been the driver for selecting the methodology, scope and scale. Priority has been given to ESs where the local management of ecosystems in Birmingham has the greatest impact on human welfare. This approach is consistent with the aim to provide best applicability and practicability for decision-making and planning purposes.

Only those ES have been mapped where the potential impact of local planning was considered to be the greatest. Different ESs occur at different scales from local (e.g. amenity) to global (global climate regulation). This investigation focuses on ESs that can be locally managed considering that the local planning system and local decision-makers have a limited influence on the management of ecosystems outside the city. Therefore, only ecosystems within the boundaries of the City of Birmingham have been evaluated.

Consequently, benefits to Birmingham's population as well as 'exported' benefits have been prioritised in case where ES flows do not only occur locally. 'Imported' ESs were not assessed within the scope of this investigation. This may be considered a supply-led approach in contrast to a demand-led approach where the wellbeing of the local population would be evaluated considering imported ES, but not exported ES.

2.3.2 Selection of Ecosystem Services to be Mapped

One of the first questions to answer when undertaking such a mapping exercise was which ES shall be mapped; and why. On the one hand, incorporating as many ES as possible into the assessment provides a more complete and more holistic picture. On the other hand, the complexity of the model increases significantly with every ES added.

As mentioned before, it was important to create information that is most useful for decision-makers and planning practitioners in Birmingham. To ensure a demand-driven approach, a steering group was set up at the earliest stages of the project. The steering group was established to oversee the project and to be consulted on key decisions. The steering group had 23 members with representation from different City Council departments including planning, local universities, government institutions such as Natural England and the Environment Agency, as well as third sector organisations such as the Birmingham & Black Country Wildlife Trust, Birmingham Open Spaces Forum and the Business Council for Sustainable Development UK.[16]

To reduce the complexity of the model, only ESs have been mapped which are/can be significantly impacted by planning decisions and considered to have the greatest impact on human wellbeing. One feasible step was to exclude ES from the mapping exercise which could be considered to lower the level of ESs provision if the land-management would be optimised for that single ES. Furthermore, ES that only have a minor effect on human wellbeing have not been mapped. Such ES have been classified as 'secondary' ESs within scope of this investigation.

The classification into 'primary' and 'secondary' ESs has been judged by the steering group. Based on a literature review and after consulting the steering group, I have undertaken a pre-selection of ESs considered to be most important in the urban UK context (Davies et al., 2011). The pre-selected ESs and their potential benefits have been summarised for the steering group members with a focus on the specific context, potential trade-offs as well as the ability of ES to be managed and affected locally. Based on the literature review, a total of 12 ESs have been considered for this specific policy context and the purpose of this project. Out of that 12 ESs, 6 have been classified as 'primary' ES and 6 as 'secondary' ES by the steering group. Figure 2.1 summarises which ESs were classified as 'primary' and which were classified as 'secondary'. Within scope of this investigation, biodiversity has been treated as an ES, even if I recognise that biodiversity is not always considered an ES itself but as an underlying concept providing ESs (Mace et al., 2012).

[16] For a full list of all steering group members see Technical Appendix 10.3 in Hölzinger et al. (2013b).

Food, timber and woodfuel production, for example, were classified as 'secondary' ESs. Woodland that is optimised for timber production usually provides a lower level of cultural and regulating services which have a higher priority in a city like Birmingham (UK NEA, 2011a). The steering group recognised the benefits of producing woodfuel in Birmingham as 'by-product' but it was the general view that woodland and trees should not primarily be managed to provide this service.

Another example is global climate regulation. Whilst the contribution of Birmingham's green infrastructure to mitigate climate change is recognised, the spatial distribution of green infrastructure within the city has a comparatively low impact on this service. To enhance global climate regulation services, the total amount of carbon sequestered and stored in vegetation and soils is important – not where in Birmingham (or elsewhere) it is stored. Therefore, it is not feasible to spatially plan Birmingham's urban green infrastructure predominantly for global climate regulation purposes.

The definition of 'secondary' ESs may be considered as a practicable approach to reduce the complexity of ESs maps in general. It should be stressed, however, that the selection of primary and secondary ESs should be judged case by case because they are very context specific. Woodland in the remote countryside not accessed by the public, for example, may indeed provide the maximum aggregated benefits if managed mainly for timber production.

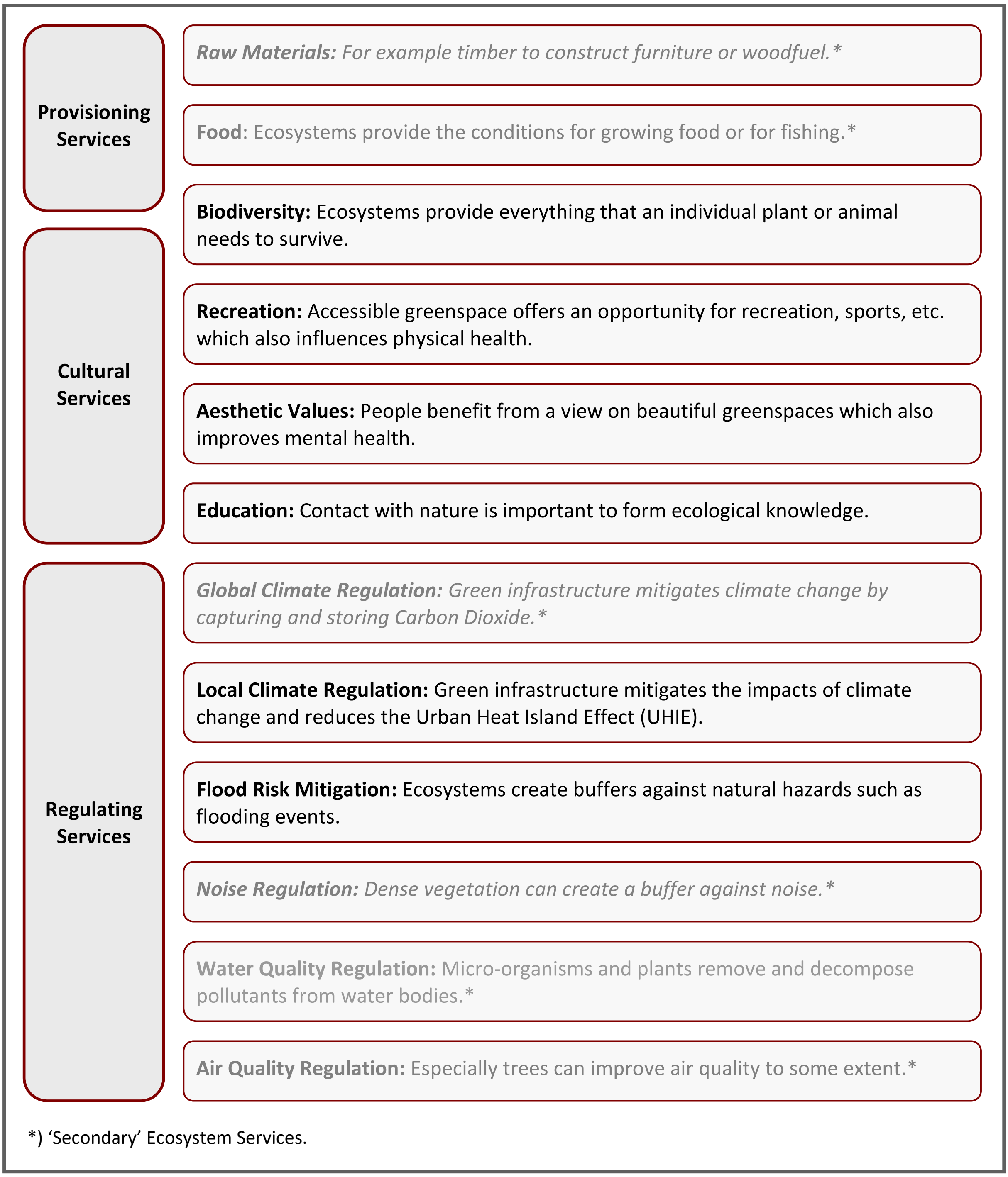


Figure 2.1 Ecosystem Services Selected for the Mapping Exercise. The figure shows ecosystem services categorised into provisioning, cultural and regulating services. 'Secondary' ecosystem services not selected for this assessment were greyed out. *Based on TEEB (2010) and UK NEA (2011a).*

2.3.3 Indicator Selection and Weighting Exercise

The availability of sufficient 'fit-for-purpose' indicators for most 'primary' ES selected for mapping was lacking when conducting this research. This applied especially for regulating and cultural services (see also Layke, 2009). But especially latter ES are of particular importance in a city like Birmingham. To define and evaluate sufficiently robust indicators for each layer and ES assessed, the initial literature review has been expanded to identify sufficient indicators to inform ESs supply and demand maps. For each ES a brief summary report has been prepared which set out (1) the main influencing variables for that ES; (2) potential indicators and data availability; and (3) opportunities to integrate such indicators into the model and maps.

At the first steering group meeting it was decided to set up specialised expert groups for different (bundles of related) ESs. Expert groups are commonly used to establish ES maps because it is efficient, fast, accessible and adaptable (Jacobs et al., 2015). Four expert groups were established as a result:[17]

1. Biodiversity (13 members),
2. Recreation, aesthetic values & sense of place, and education (14 members),
3. Local climate regulation (17 members), and
4. Flood risk regulation (18 members).

The members of the expert groups were mainly nominated by the steering group members alongside experts from local universities, agencies, and third sector organisations. Summary reports for each of the 7 assessed ES have been presented to and discussed with the expert groups. For each of the 4 (bundle of) ESs listed above, a workshop was organised during July 2012. The workshops took place in Birmingham.

Based on the provided summary reports, the expert groups discussed and selected feasible indicators and variables for the different layers at the workshops which were facilitated by me. Examples for indicators and variables are the distance to greenspaces, the population density, or the size of a habitat.

Based on the expert workshop outcomes, the summary reports were updated and experts (including those who could not attend the workshops) were given another opportunity to comment on that revised documents. Remaining disagreements were resolved via email or

[17] For a full list of all expert group members see Technical Appendix 10.3 in Hölzinger et al. (2013b).

follow-up meetings with members of the expert group. In the end all experts had sufficient confidence in the defined indicators, while acknowledging the limitations and caveats.

To implement expert judgement in the model, relative weightings of different variables and ESs were based on expert knowledge rather than a review of published evidence (see also Jacobs et al., 2013). The approach can be defined as an expanded matrix model where not only the land-use (greenspace) classes but also other influencing variables such as distance to a greenspace (in the example of recreation) receive an expert score or weight, is a practical approach to quantify and map ESs (see Jacobs et al., 2015 for an overview).

Microsoft Excel-based weighting exercises were prepared for each of the 6 primary ESs assessed. The weighting exercises were shared with expert group members via email with the appeal to also forward them to relevant colleagues. Within these exercises, the respondents were asked to ascertain weighting scores to different scenarios and ESs. Participants were asked to ascertain a baseline score on a scale from 0 to 10 to different land-use classes, reflecting the level of ES provision from that land-use class in Birmingham. Afterwards they were prompted to ascertain weighting score advances or penalties incorporating other influencing variables such as location of a site or environmental quality. Participants were then asked to ascertain weightings to compare the relative contribution of the 6 assessed ESs to human wellbeing in Birmingham. This step was necessary to aggregate the different ESs maps to one 'blueprint' for the city. In a second round, participants were given the opportunity to review aggregated scores. Altogether 28 weighting exercises were completed (see Technical Appendix 9.1 in Hölzinger et al. 2013b). A comparable scoring approach has also been applied to the Eco-metric toolkit in England (Smith et al., 2018).

Weightings were then aggregated and used to create the ES layers which is demonstrated below using the example of education. For more detail about how the weighting scores have been defined and integrated for other ESs maps see Chapter 4-6 and Appendix 9.2 in Hölzinger et al. (2013b).

2.3.4 Mapping Framework

The literature review did not reveal a fit-for-purpose spatial mapping framework suitable for this project. Therefore, a bespoke framework for mapping ESs in Birmingham was developed.

Although based on Birmingham, this framework is applicable to other ESs mapping exercises at a variety of different scales.

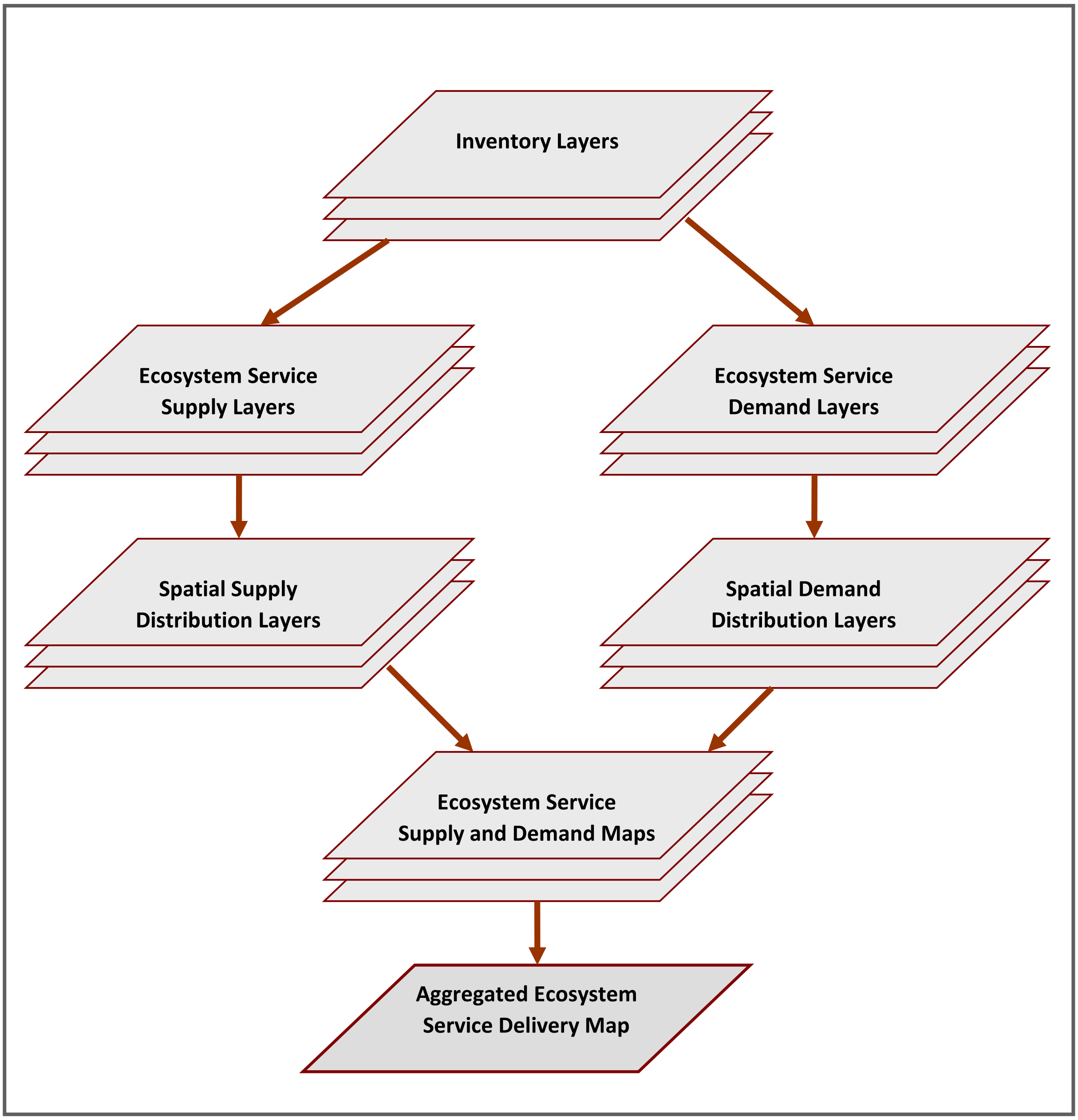


Figure 2.2 Ecosystem Services Mapping Framework. The figure shows the inventory layers at the top. These inform the respective ecosystem services supply and demand layers. To acknowledge the spatial distribution of supply and demand, also spatial distribution layers were created for each ecosystem services. The spatial distribution layers were then aggregated into a single supply and demand map for each assessed ecosystem service. Finally, all supply and demand maps were combined to an aggregated ecosystem service delivery map or 'multiple challenge map for Birmingham'.

Inventory layers

The inventory layers gathered spatial data on the biophysical and social system relevant for an ES assessment (Fisher et al., 2011). Relevant layers for this investigation included land cover classes, habitat types and local population density. Layers were selected dependent on their ability to provide feasible indicators and proxies to inform the ES supply and demand layers as well as the spatial distribution layers (see below).

Ecosystem Service Supply Layers

For each assessed ES, a supply layer was created based on relevant inventory layers, available scientific evidence as well as expert knowledge (Section 2.3.5 for more details on how these layers were created in Birmingham using education as an example).

> *"Supply of ecosystem services refers to the capacity of a particular area to provide a specific bundle of ecosystem goods and services within a given time period."* (Burkhard et al., 2012, p. 18)

The supply is generated by the 'ecosystem function'. De Groot (1998, p. 7) defines 'ecosystem function' as:

> *"the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly."*

It is clear that not all land-use options have the same capacity to provide the same bundle of ES to the same extent. The capacity depends on soil type, accessibility, biological quality, visual amenity and so on. The data availability to identify and define indicators for mapping ES supply layers is comparatively poor (Layke, 2009). Therefore, I often had to define bespoke indicators for this project.[18] A weighting matrix was developed to define the relative capacity of land cover classes to provide different ESs.

Ecosystem Service Demand Layers

When mapping ES it is crucial to also consider the demand side. It is important to evaluate where potential beneficiaries are and if and how they utilise the supply.[19] Burkhard et al. (2012) define the demand for ESs as *"the sum of all ecosystem goods and services currently consumed or used in a particular area over a given time period."* (Burkhard et al., 2012, p. 18).

[18] For more details on how indicators were developed see Hölzinger et al. (2013b).

[19] It should be noted that the maps I produced indicate where supply and demand coincide in space. It could not be assessed if and to what extend the supply of ESs is actually being utilised by people. This was beyond the scope of this assessment.

However, for the purpose of this investigation it was possible to incorporate the unsatisfied and potential demands as well. People may be willing to pay for a good or service but the supply of that good may be insufficient or the transaction costs[20] are too high. One example is recreation. People in an area with no public greenspaces may desire such space as much as their counterparts in an area with greenspace. However, locally there is no opportunity (supply) and the transaction costs (fuel, travel time etc.) to access such greenspace further away may be too high. Consequently, the demand remains unsatisfied even if it exists. Therefore, I define ES demand as follows:[21] *The demand for ecosystem services is the sum of all ecosystem goods and services currently consumed, used* ***or desired*** *in a particular area over a given time period.*[22] (Based on the definition by Burkhard et al., 2012, p. 18).

Spatial Supply & Demand Distribution Layers

These layers are important because the benefits ESs provide are not necessarily realised at the same location where they are provided. ESs spread through the landscape, for example influenced by wind or stream direction (Balzan et al., 2018; Fisher et al., 2011). One may also use the term service flow. However, in the ES context the term 'flow' is commonly used to explain the distinction between the stock and the flow of ES rather than the spatial distribution of such flows (Kienast et al., 2009). This is why I use the term 'spatial distribution'.

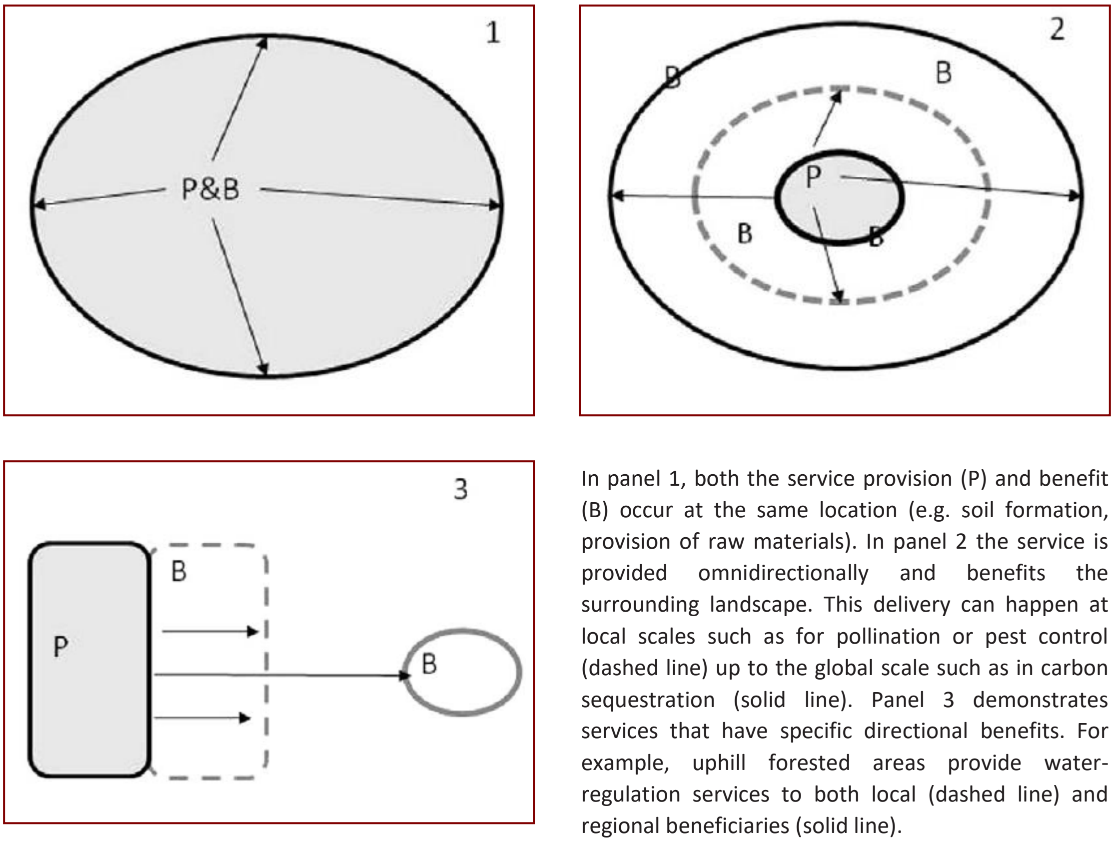
Fisher et al. (2011) distinguish between three spatial relationship categories:

- **In situ**, where the services are provided and the benefits are realized in the same location,
- **Omni-directional**, where the services are provided in one location, but benefit the surrounding landscape without directional bias, and
- **Directional**, where the service provision benefits a specific location due to the flow direction.

[20] In economic theory transaction costs are the costs incurred in making an economic exchange or participating in a market. However, that does not only affect markets, it also affects transactions related to goods and services where no 'real' market exists (e.g. because no property rights can be defined or goods and services are not exclusive).

[21] I consider that this definition might be criticised because when a demand is only desired but not satisfied one may take into question if you can use the term 'ecosystem service'. However, this thesis is written for a broader audience and using another phrase in this context might be more confusing rather than helpful.

[22] Based on (Burkhard et al., 2012, p. 18)



In panel 1, both the service provision (P) and benefit (B) occur at the same location (e.g. soil formation, provision of raw materials). In panel 2 the service is provided omnidirectionally and benefits the surrounding landscape. This delivery can happen at local scales such as for pollination or pest control (dashed line) up to the global scale such as in carbon sequestration (solid line). Panel 3 demonstrates services that have specific directional benefits. For example, uphill forested areas provide water-regulation services to both local (dashed line) and regional beneficiaries (solid line).

Figure 2.3 Spatial Relationships Between Service Production Units and Service Benefit Units. The figure shows options of how ecosystem services distribute through space. *Adapted from Fisher et al. (2011), p. 601.*

When focusing on the ability to aid decision-making, the spatial distribution of ES demands should be integrated in such a model as well. In this case, not only the physical ability of ES to distribute through space (for example purified air flowing from a woodland to a populated area) is crucial – it is often the transaction costs that limit humans benefiting from an ecosystem and its potential benefits. People may have a desire to access a public greenspace for recreational purposes but the travel costs including costs of time (the transaction costs) may be too high if the greenspace is far away from where they live. Without knowing or developing feasible assumptions about the spatial distribution of ESs supply and demand, it is hardly possible to derive practicable information for planning purposes.

Ecosystem Service Delivery Maps

After evaluating supply and demand of ESs as well as the spatial distribution of flows, those layers have been combined for each ES assessed. The aim was to provide an indicative map that identifies areas of the city where the demand for a specific ES cannot be sufficiently satisfied and under provision is this outcome. These maps serve as decision-aid to prioritise areas related to a specific policy agenda – for example flood risk management. Mismatches between supply and demand can be identified both, at the city level but also at the neighbourhood level. The maps also indicate areas where actions regarding a specific ES may be most and least benefiting, respectively.

Aggregated Ecosystem Services Delivery Map

When optimising multifunctional landscape management for human wellbeing, all important or significant ESs should be taken into account. Therefore, I aggregated all ES maps to a single map. This aggregated ESs delivery map helps (1) to prioritise areas where the demand for ES cannot be sufficiently satisfied; and (2) to identify ES 'hotspots' which are providing a very high value across a wide range of benefits.

The former indicates in which areas of Birmingham a specific need for the creation and/or enhancement of green infrastructure exists. The latter indicates where existing green infrastructure is very valuable and will require specific protection/measures. This may well be areas that do not have formal designations.

It should be noted that the ESs delivery map (or 'blueprint') should not be the only information basis for action – it is a decision-aid, not a decision substitute. The map is indicative and should be interpreted as a starting point when identifying areas of Birmingham which may demand further investigation. However, it is advisable to 'ground-truth' the information provided by the ESs delivery map before deciding on interventions.

2.3.5 Creation of Ecosystem Services Supply and Demand Maps Using Education as an Example

Frequent interaction with the natural environment is one key element of acquiring ecological knowledge (Mourato et al., 2010). In urbanised areas, greenspace is capable of playing an even more important role in education (Gómez-Baggethun et al., 2013; Krasny et al., 2013). Children who have grown up in cities like Birmingham usually do not have the same emotional connection with nature as their counterparts living in the countryside due to a lack of nature experiences (Soga et al., 2016; UK NEA, 2011b).

Children in Birmingham have access to environmental/ecological education through a variety of sources. Individual educational establishments make arrangements directly to visit local open spaces or via the Birmingham City Council Ranger Service. There are also a number of outdoor education establishments and more and more schools are creating forest school areas either on their own sites or in local public open spaces – developing the idea that environmental education takes place where you live and study and not in disconnected external places. Many young people also gain ecological education experiences as part of out of school activities with youth organisations as for example Scouts, Woodcraft Folk and the Duke of Edinburgh and John Muir Awards.

Below I outline how the different spatial supply and demand layers and maps were generated for the ES education. The example of education is used to explain how the methods for creating the results (ESs supply and demand maps and aggregated 'blueprint for Birmingham') were generated. It is recognised, of course, that ecological outdoor education is only one element of education. For further details on how maps for other ESs (biodiversity, recreation, aesthetic values, local climate regulation and flood regulation) were created, please refer to Hölzinger et al. (2013b).

2.3.5.1 Education Supply Layer

The following indicators were used when developing the education supply layer:

<u>Accessibility</u>

Accessibility to relevant sites is necessary to benefit from outdoor education. Because of limited data availability to develop and apply alternative approaches, only publicly accessible greenspaces have been assigned a supply score within scope of this investigation. Unfortunately, data about outdoor education facilities on the school grounds were not available. Inventory layers to be included were country parks, parks, public open spaces and private open spaces.

Indeed, a private garden also provides educational benefits. However, the number of potential beneficiaries is usually small and the Council's impact on how private gardens are managed is very limited. For the purpose of simplification, but also because of limited data availability to develop and apply alternative approaches, only green infrastructure that is accessible on a day-to-day basis by a wide range of potential beneficiaries has been assigned an educational value within scope of this investigation.

Diversity of habitats

The expert group agreed that the diversity of different types of habitats is the better indicator for the capacity of a site to provide educational benefits than the actual types of habitat(s). This is feasible as the range of learning/nature experience opportunities increases with the number of different habitats. It has been shown before that people have a preference for visiting/experiencing diverse habitats as opposed to homogeneous habitats (Graham and Eigenbrod, 2019; Ridding et al., 2018). Different weighting scores have been assigned to different numbers of habitats located on one site. The following categories were defined by the expert group:

- Sites containing 1-2 different habitat types,
- Sites containing 3-4 different habitat types,
- Sites containing 5-6 different habitat types,
- Sites containing 7-8 different habitat types, and
- Sites containing 9 or more different habitat types

For the scores applied to each category please refer to Table 2.1.

Green Flag Award

There is evidence that the quality of a greenspace has an impact on its use (Public Health England, 2014). It is therefore arguable that the quality of a greenspace also has an impact on its ability to provide educational services because the more people (and especially children) are attracted by and use a greenspace, the more people are likely to benefit from educational services.

In the UK, the Green Flag Award is a main benchmark for high quality greenspace:

> *"The aim of the Green Flag Award is to ensure that everyone has access to a quality green space and to enable them to live more healthy lifestyles."*
> (Keep Britain Tidy, 2016a)

Green Flag Award applications are judged against 27 criteria across 8 sections: (1) a welcoming place; (2) healthy, safe and secure; (3) well maintained and clean; (4) environmental management; (5) biodiversity, landscape and heritage; (6) community involvement; (7) marketing and communication (including the criterion 'appropriate educational and interpretational information'); and (8) management (Keep Britain Tidy, 2016b).

It has been agreed by the steering group that the Green Flag Award is the best available indicator to account for greenspace quality in Birmingham. To reflect this, higher scores have been assigned by the expert group to greenspaces which have a Green Flag Award (see Table 2.1).

2.3.5.2 Education Spatial Supply Distribution Layer

Green infrastructure has to be accessible to be able to provide educational benefits. The benefits are realised at the same location as they occur (in situ) - for example in a park or woodland. Consequently, the supply layer equals the spatial supply distribution layer.

Panel 1 in Figure 2.4 indicates where the greenspaces with the highest educational values in Birmingham occur. These scores depend on the habitat diversity as well as if the site has been awarded a Green Flag Award. Table 2.1 shows the scores which have been determined by the expert group:

Table 2.1 Education Spatial Supply Distribution Layer Scores. The table shows the scores allocated by the stakeholder group; depending on the habitat diversity on site and whether the site has a Green Flag Award.

Habitat diversity on site	**Score with Green Flag Award**	**Score without Green Flag Award**
Sites containing 9+ different habitat types	10	8
Sites containing 7-8 different habitat types	*9*	*7*
Sites containing 5-6 different habitat types	8	7
Sites containing 3-4 different habitat types	*7*	*5*
Sites containing 1-2 different habitat types	*5*	*4*

2.3.5.3 Education Demand Layer

Population density of young people

Educational knowledge is not only provided by the formal educational system. There is evidence indicating that basically every contact with nature adds to ecological experience such as through the use of interpretative services offered at public parks (Cable et al., 1984; Church et al., 2011; Hill, 2013; Hutcheson et al., 2018; Mocior and Kruse, 2016). Accordingly, a general demand by children and young people for accessible greenspace close to where they live can be assumed not just for recreational purposes, but also for accumulating environmental experience. This is irrespective of a visit to a park or greenspace being formally organised as part of the education system such as an organised school trip. It is also sensible to assume that, the more children live in an area, the higher is the demand in terms of accumulating environmental experience and therefore the demand for greenspace access.

To take this demand into account, a demand layer was created for a subset of Birmingham's population aged 18 or below using data from the Office for National Statistics (ONS). Weighting scores (from 0 to 10, consistently with other scoring ranges of this exercise) have been assigned linear to the number of children per ha which range between 0 and 40 children per ha, assessed at the Lower Super Output Area (LSOA) level. The distribution of Birmingham's children population density is shown in panel 2 in Figure 2.4 where a darker blue colour shading indicates a higher demand for greenspaces for outdoor education purposes.

Educational facilities

One important way to improve children's ecological knowledge is within the formal educational system. Outdoor education can add to ecological knowledge and experience (Mourato et al., 2010). To take this factor into account, demand weighting scores were generated for different types of educational facilities including nursery schools, primary schools, secondary schools, special schools and further education establishments.

Based on agreement of the relevant expert group, the highest demand weighting score of 10 has been assigned to all education establishments. It was assumed that the demand for accessible greenspace is equally high around all such education establishments. In the future this may be refined by for example incorporating the number of pupils of the different schools.

If a school accommodates more children, it can be assumed that the demand for outdoor education facilities increases as well because there are more (potential) beneficiaries. However, relevant data were not accessible at the time of this investigation.

2.3.5.4 Education Spatial Demand Distribution Layer

Distance from home

For 'general' outdoor education demand, (potential) benefits occur at different locations. Most children in Birmingham do not live on the doorstep to accessible greenspace. They have to travel a certain distance to access it to benefit from its services. However, with increasing distance, the opportunity costs (including the time of travel that could be spent on other activities) to access the greenspace rise as well (Bateman et al., 2006).

I also recognise that scale-dependencies are a driver for different outdoor recreation activities such as 'day-to-day' recreation (e.g. walking a dog) or 'destination' recreation (to visit/experience a specific place or landmark) (Graham and Eigenbrod, 2019). However, I assume that ecological experience is virtually gained as part of every visit to a greenspace, irrespectively of the main purpose of the visit. This is why I do not apply scale-dependencies depending on the purpose of a greenspace visit.

Natural England's Accessible Natural Greenspace Standard (ANGSt) recommends a straight line distance to accessible greenspace of 300m from home as a proxy for a 5 minutes' walk, recognising the longer actual walking distance to access the nearest greenspace access point (Handley et al., 2003). I adopted this 300m buffer recommendation around greenspaces as proxy for the 'spatial demand distribution layer'. The assumption applies that, due to reduced opportunity (travel) costs, children within a 300m buffer around accessible greenspaces are most likely to realise outdoor education benefits.

Distance from educational establishments

The assumption is feasible that accessible greenspace close to educational facilities can be used more frequently for formal outdoor education purposes than greenspaces further away. If a greenspace is located within walking distance to a school, the transaction costs of for example planning a school trip including potentially having to rent a coach etc. decline significantly. The travel time declines as well. Therefore, the highest demand weighting score of 10 has been assigned to a 300m buffer around all education establishments in Birmingham. The highest demand 300m buffers around education establishments can be reviewed in panel 2 of Figure 2.4. The demand in areas not within these 300m buffers is determined by the local population density of children.

2.3.5.5 Education Supply and Demand Map

To generate an aggregated education supply and demand map for Birmingham, the demand scores were multiplied by -1 resulting in a scale from 0 to -10. The negative scores of the demand distribution layer (0 to -10) and the positive scores of the supply distribution layer (0 to 10) have then been aggregated for each location.

In each spatial location (mapped at a 10*10 metre raster), the score aggregation resulted in a score from +10 (highest supply and zero demand) to -10 (zero supply and highest demand). These scores have then been visualised through a colour code where -10 is shown as dark red and +10 is shown as white (Panel 3 in Figure 2.4).

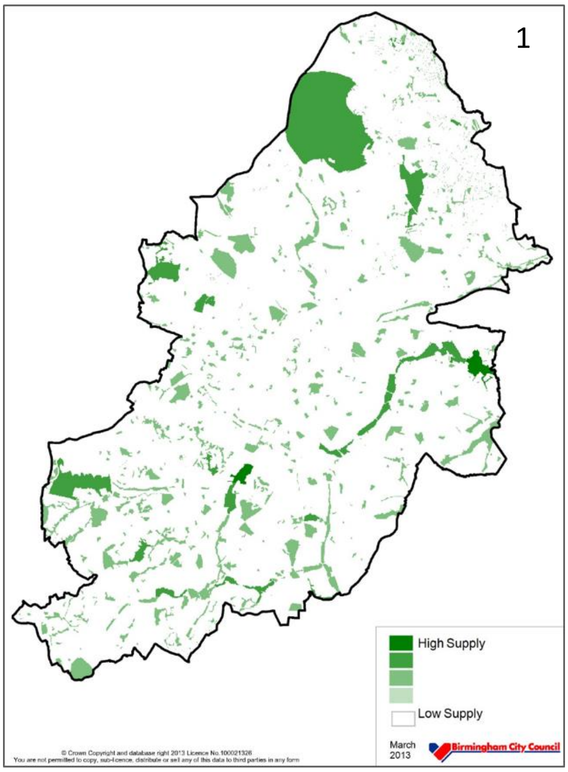
2.4 Results

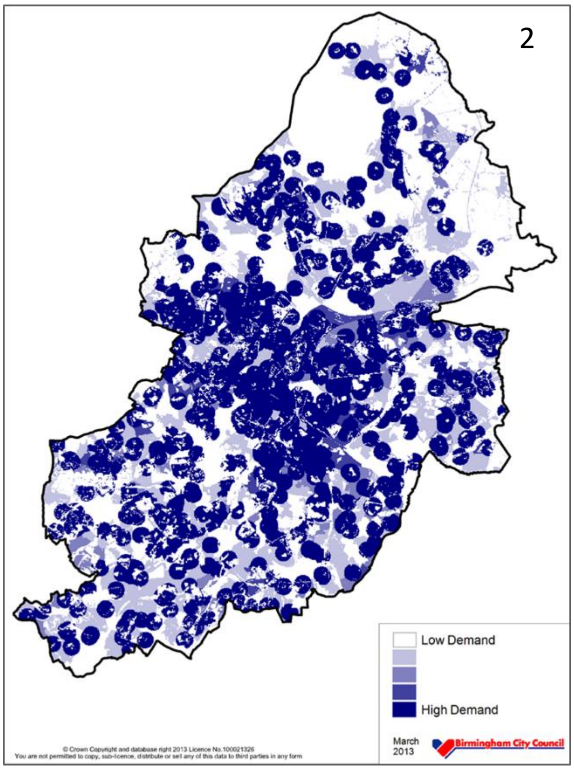
2.4.1 Education Supply and Demand Maps

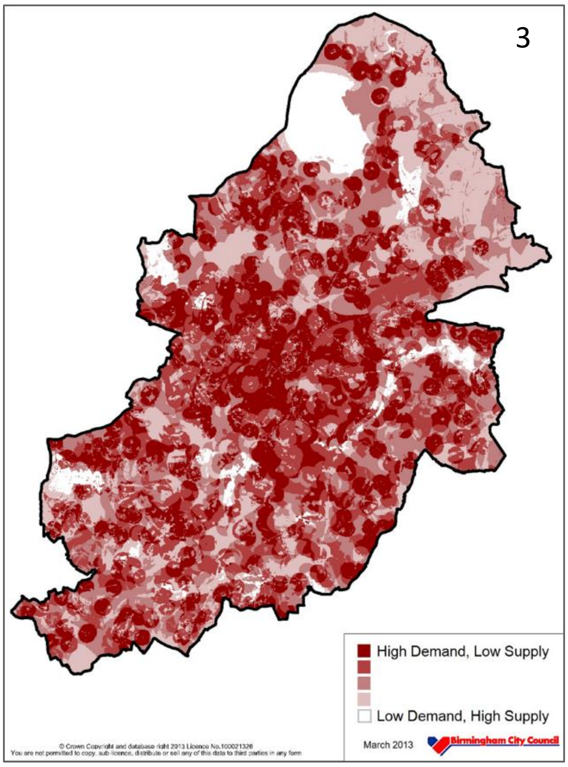
Here, I present the results of the education supply and demand maps which I used as an example to explain in Section 2.3 how the methods for this exercise were developed. Panel 1 in Figure 2.4 indicates the supply with greenspaces as outdoor educational opportunities in Birmingham. The highest scores (darkest green shading) are for accessible greenspaces with a variety of different habitat types that also have a Green Flag Award. A zero-score (white colour) is assigned to areas that are not accessible greenspaces.

Panel 2 shows the distribution of the demand for outdoor educational opportunities. The highest demand is indicated for areas within 300m from formal education institutions such as schools (dark blue circles). In other areas, the demand is determined by the local population density of children where dark blue indicates a high population density and light blue a low density.

Panel 3 shows the aggregated demand and supply map which is effectively an aggregation of Panel 1 and Panel 2. Dark red indicates a comparatively high demand matched by a low supply whilst white indicates a comparatively high supply matched by low demand. This map can be used to target the effective creation and/or enhancement of greenspaces in Birmingham for educational purposes.







Panel 1 shows the spatial supply distribution layer where a higher supply with the ES education is indicated by a darker green colour shape.

Panel 2 shows the spatial demand distribution layer where a higher demand is indicated by a darker blue colour shade.

Panel 3 shows the aggregated supply and demand map for outdoor education in Birmingham. This map indicates where the demand for outdoor education and supply of outdoor education opportunities coincide in space.

Figure 2.4 Education Supply and Demand Maps. The figure shows the spatial supply and demand distribution layers and the aggregated supply and demand map. *Source: Hölzinger et al. (2013b).*

2.4.2 Aggregated Multi-layered Challenge Map for Birmingham

The main result of this assessment is a set of 6 ESs supply and demand maps and an aggregated 'multi-layered challenge map for Birmingham' as shown in Figure 2.5. These maps indicate (1) areas in Birmingham where the creation/improvement of green infrastructure might be most beneficial (dark red colour shape); and (2) 'ES hotspots' (bright colour shape) where green infrastructure requires specific protection to ensure that ecosystems providing a bundle of particularly high levels of ESs are not lost, for example due to development. This set of maps is the starting point for enabling the Council and other organisations with a stake in Birmingham's green infrastructure to prioritise areas for action in terms of greenspace protection, creation and enhancement.

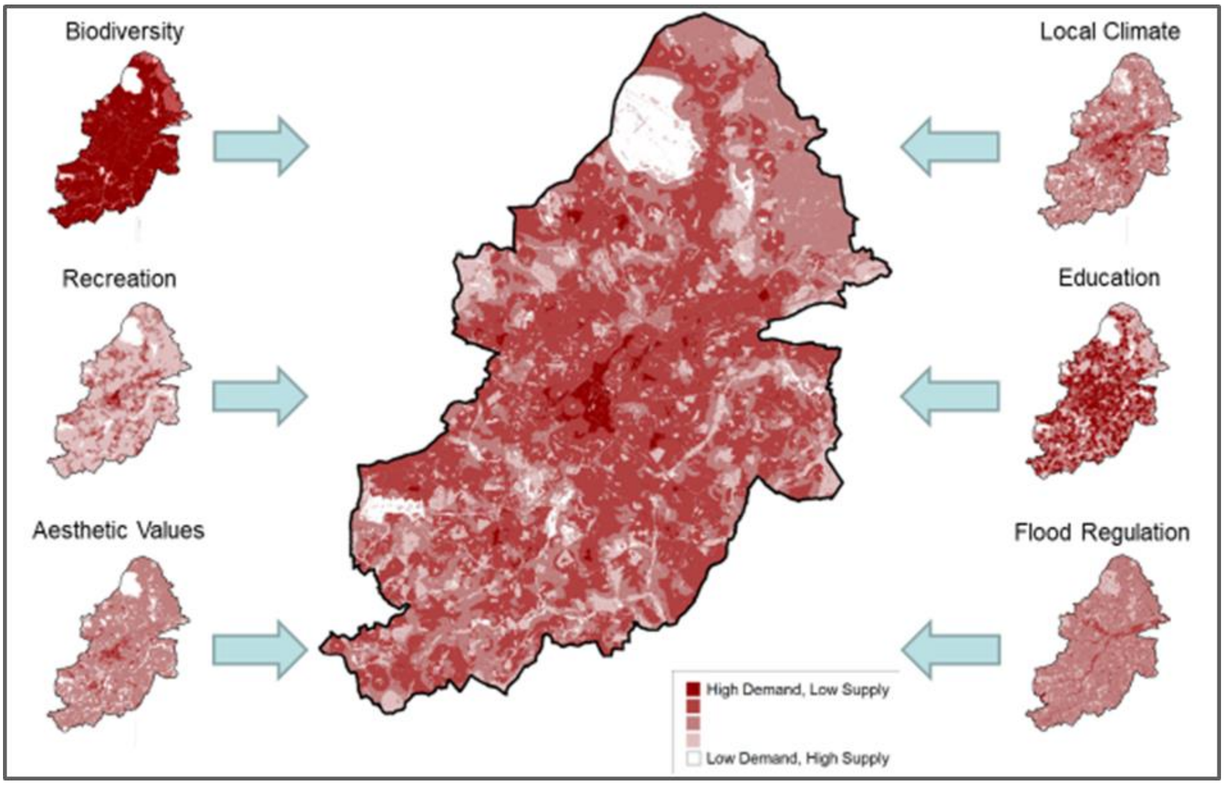


Figure 2.5 Multi-layered Challenge Map for Birmingham. The figure shows the ecosystem services supply and demand maps for biodiversity, recreation, aesthetic values, local climate regulation, education and flood regulation; as well as the aggregated 'multi-layered challenge map for Birmingham'. *Source: Hölzinger et al., 2013b.*

2.5 Discussion

Mapping NC and ES is becoming more and more recognised as a valuable tool to support land-use decisions (Burgess et al., 2016; Jacobs et al., 2015). The European Union for example encourages member states to map ES at the national scale in its Biodiversity Strategy 2020 (European Union, 2011). However, the incorporation of the demand-side in such mapping approaches remains limited as ES mapping approaches often only attempt to map ES supply such as through matrix models where experts simply assign values to land-use classes (Jacobs et al., 2015). Here, I extended this simple matrix model by also assigning scores to the demand side. Furthermore, I incorporated more context-specific variables beyond land-use class such as quality and location indicators (e.g. flood risk zones) to add more detail to the model (see also Smith et al., 2018).

Mapping ES supply and demand remains a challenge with respect to indicator availability and gaps in the published evidence on the values provided by different land-uses (also depending on ecosystem quality/location) and distribution (where and how do ES supply and demand flow through space) (Burgess et al., 2016; Jacobs et al., 2015). Here, I attempted to bridge the data and evidence gap as well as possible, acknowledging time and resource constrains. This required me to incorporate untested and proxy evidence and also to 'fill the gaps' with expert judgement. The alternative would have meant excluding some ESs completely from the assessment such as cultural ES which are more difficult to map and quantify but also particularly important especially in the urban context as in my case study Birmingham (Davies et al., 2011). Non-inclusion effectively assigns a zero-value to such services. This could consequently lead to biased or at least sub-optimal decisions and outcomes. Especially given that land-use decisions cannot easily be reversed and affect generations to come, this was not desirable. And in some cases, such as when removing ancient woodland, they can never be reversed. This is why this mapping approach has been driven by the relevant decision-makers from the start – to map the ES that are most relevant rather than those that are easier to map.

However, I recognise that the maps presented here are indicative and decisions cannot entirely be based on them. Limitations of the approach and the scale of the assessment will make a case by case evaluation and justification of 'action on the ground' necessary. One trade-off I had to balance when selecting, defining and modelling the indicators informing my model was that of complexity. On the one hand indicators should be as accurate and detailed as possible; on the other hand, they should be easily accessible and tangible for the end-users of the maps. For this investigation I gave the latter a higher priority and reduced complexity as far as was sensible. I considered for example the limited data availability and lack of scientific evidence when 'translating' indicators into ESs layers. Future improvements in the scientific evidence will advance more complex models that allow incorporating and combining more indicators and therefore making the maps more accurate. However, when undertaking such steps, the accessibility and tangibility by the user should always be considered as there is little benefit in producing evidence that cannot be meaningfully utilised by decision-makers (Daily et al., 2009).

One feasible next step is to investigate areas of the city where an under provision with ES has been identified as part of this exercise. This should include an assessment of whether opportunities for the creation and improvements of green infrastructure exists in such areas. Such a process should involve local land-owners, the local population and relevant stakeholders (Raum, 2018). This would result in an opportunity map for the creation/enhancement of green infrastructure in Birmingham which could guide investment to the most beneficial areas.

Another problem that cannot be solved by ES mapping studies is the definition of the optimal land-use option and land-use management for identified sites. The maps indicate where a land-use change could be beneficial but not which kind of land-use change is most beneficial. Such a decision is very context-specific and requires further case-by-case investigation. The 'multiple challenge map for Birmingham' can indicate where action in terms of green infrastructure interventions should take place; but not which action in detail (Haines-Young et al., 2012; Hölzinger et al., 2014a, 2015). When taking action on the ground, it is important to consider the multifunctionality of green infrastructure (Wainger et al., 2010). Many ecosystems provide a whole bundle of ESs if managed for multifunctionality. The sum of benefits provided by multifunctional green infrastructure often outweighs the benefits of optimising an ecosystem for providing a single ES (de Groot et al., 2010; UK NEA, 2011a). Ecosystems may be created and managed optimised for a specific policy agenda by developing and managing the ecosystem for maximising it for a single ES.

The institutional setup of responsibilities with respect to land-use decisions often encourages this sub-optimisation. Different agencies and (local) Government departments often focus on optimising the benefits of a specific (bundle) of ESs. This can lead to disregarding other ES that do not fall into their area of responsibility. The result of this sub-optimisation can be that ecosystems will not perform to their full ES potential. Hence, stronger partnership approaches across agencies and Government departments, but also stakeholders, would be beneficial to use limited space in the best way (Bastian et al., 2012; Daily et al., 2009). The mapping of ES can help to facilitate such collaborative approaches (Jacobs et al., 2015). It is hoped that the production of these maps helps to encourage stronger partnership work on land-use decisions in Birmingham as it highlights the benefits of multifunctional green infrastructure capable of contributing to a range of policy goals at the same time and from the same space.

If trade-offs with other ES are not taken into account, the ecosystem may provide the highest benefits for a single ES, but not for the sum of ES potentially provided by the ecosystem. This is why the ESs maps presented here should be used together rather than in isolation. The Natural Capital Planning Tool (NCPT) can for example be used to optimise the land-use design for a certain bundle of ESs which are in undersupply in an identified area (Chapter 5). But consideration should also be given to ES that may be reduced as a consequence of the intervention; even if the maps did not initially indicate a low supply. In certain cases, especially for large-scale interventions, an update of the maps based on the preferred options for green infrastructure interventions may be considered to avoid adverse impacts such as reducing the provision of existing ES.

The costs of habitat creation and management also needs to be taken into account before interventions takes place. The maps do not incorporate (potential) management costs for creating/enhancing green infrastructure, which was outside the scope of the study. After a site has been identified for land-use interventions, Cost-Benefit Analysis (CBA) could be used to overcome this caveat and compare different land-use options at the project scale with respect to economic viability. Here, it is important to also incorporate social and environmental values rather than just financial value in such assessments (Hölzinger et al., 2014b; Sunderland and Hölzinger, 2013). These considerations highlight that the 'multiple challenge map for Birmingham', and ES mapping in general, is not a 'magic bullet tool' but rather part of a wider box of tools which accompany each other (see also Scott et al., 2014).

An opportunity for the future could be to investigate especially imported ESs in Birmingham and how the flow of such ES may change in the future. The concept of ES footprints might be applied to evaluate this effect (Burkhard et al., 2012). This would reveal Birmingham's dependence on ESs 'produced' outside the city boundaries. Partnerships and instruments such as Payments for Ecosystem Services (PES) might be considered to ensure the sustainable flow of such ESs benefiting human wellbeing in the city.

2.6 Conclusions

The data presented here was generated to assist Birmingham City Council to strategically plan green infrastructure interventions at the city scale and to invest limited resources effectively. This, in turn, can help to mitigate inequalities across the Birmingham population in terms of benefiting from ESs because most disadvantaged areas can be prioritised using the produced maps.

However, the production of these ES supply and demand maps and the aggregated 'multi-layered challenge map for Birmingham' are only one element in enabling better informed land-use decisions. Other tools applicable at the project scale are also required to further refine information as well as informing which kind of land-use intervention should be selected (Chapter 5). The findings of the work are a starting point for planning and community evaluation – not a comprehensive delivery or protection plan.

3 Chapter Three: Ecosystem Assessments – Lessons from Birmingham[23]

3.1 Abstract

This Chapter explores how Ecosystem Assessments and ecosystem valuation can serve decision-making at the municipal scale and how to make best use of existing evidence. I analyse the specific demands of local decision-makers for evidence about the value of ecosystem services (hereafter ES) and evaluate which barriers prevent better implementation of the ES concept at the municipal level. I argue that improved information is not only needed at the national and international level, but also at the local and regional level which is the scales at which planning and policy decisions affect ecosystems. Considering the everyday circumstances of the decision-makers, relevant evidence has to be presented in a 'fit for purpose' format that can easily be accessed and operationalized.

I present a case study of an Ecosystem Assessment for Birmingham, UK, that provides an important first step towards integrating the value of ES into everyday decision-making at the municipal scale. This is the first city-wide Ecosystem Assessment of this kind the author is aware of. I conclude with a call for demand-driven, bottom-up research acknowledging the key role that political institutions play in this process.

3.2 Introduction

With 3.6 billion urban residents, about 50 per cent of the world population is living in urban areas now. This figure is projected to increase to 6.3 billion by 2050 (UN, 2012). This rapid urbanisation has caused significant changes in land-use over the last few decades and is likely to put significant additional pressure on urban ES in the future (Dallimer et al., 2011;

[23] The content of this Chapter was previously published as a journal paper: Hölzinger, O., Horst, D. van der, Sadler, J., 2014. City-wide Ecosystem Assessments—Lessons from Birmingham. Ecosystem Services 9, 98–105. https://doi.org/10.1016/j.ecoser.2014.05.003. The contents of the journal paper were partially based on a report which was published as Appendix 1 of Birmingham's Green Living Spaces Plan (Birmingham City Council, 2013): Hölzinger, O., Grayson, N., Christie, M., Coles, R., 2013. Ecosystem Services Evaluation for Birmingham's Green Infrastructure. Birmingham City Council, Birmingham. The co-authors listed above provided editorial comments. Please note that the content of this Chapter reflects the state of the art at the time of the publication date (2014). Given that the work is already published in a journal it was not updated for inclusion in this thesis.

Eigenbrod et al., 2011). A commonly used definition for ES is *"the benefits people obtain from ecosystems"* (Millennium Ecosystem Assessment, 2005). But even if urban regions are the focal point of ES demands as well as a primary source of global environmental impacts (Kroll et al., 2012), urban ES are rarely discussed within the literature and the theoretical foundation is less well developed than for other landscapes (Bastian et al., 2012).

The aim of this paper was to address the research gap of a comprehensive Ecosystem Assessment and ecosystem valuation at the city-scale and assess how this information can be used for policy and project level policy design and implementation. I explored the specific demands of local decision-makers for evidence about the value of ES and evaluate which barriers prevent a better implementation of the ES concept at the municipal level (see also Honey-Rosés and Pendleton, 2013). The hypothesis was that relevant ES evidence (including ecosystem valuation) is not only required at the national and international level, but also at the municipal level where many planning and policy decisions affecting ecosystems take place.

Within past few decades the research addressing ES has become an important field and the numbers of relevant peer-reviewed papers rose exponentially (Fisher et al., 2009). ES have become a widely accepted framework within the academic community for the purpose of informing decision-making (Hermann, 2011; Kienast et al., 2009). The ES concept and ecosystem valuation is recognised to have a great potential to serve decision-making; allowing better informed and more rational decisions whenever ecosystems are affected (Bastian et al., 2012; Bingham et al., 1995; Fisher et al., 2009; Lundy and Wade, 2011; Turner and Daily, 2008; Wainger et al., 2010). Notwithstanding this, numerous authors (Daily et al., 2009; Daily and Matson, 2008; Kroll et al., 2012; Laurans and Mermet, 2014; Layke, 2009; Primmer and Furman, 2012; Shi, 2004) have suggested that the ES concept still plays a relatively minor role in real-world policy and planning decisions.

In this paper I present a case study of a comprehensive Ecosystem Assessment for Birmingham, UK, that acknowledges the demands of decision-makers and provides an important first step towards integrating the ES concept and the value of ES into local decision-making which is a remaining challenge (Daily et al., 2009). At the time of publication, a city-wide Ecosystem Assessment had not been implemented and to the best of our knowledge, this Birmingham case study was the most comprehensive Ecosystem Assessment and ecosystem valuation at a city-scale to date.

Municipal Ecosystem Assessments allow to produce more relevant evidence and values (compared to national Ecosystem Assessments) matching the specific information demands of the local decision-makers. The case study presented in this paper provides local decision-makers, bureaucrats, but also other relevant stakeholders with the magnitude of the (monetary and non-monetary) value of ES in Birmingham. Above all the assessment has an information function. The evidence base can help relevant actors to get a better understanding of the value trade-offs inherent in decisions affecting ecosystems; and consequently, improves decision-making enhancing human wellbeing in the urban environment. This applies especially for small-scale decisions where project-specific evaluations such as Multi-Criteria Decision Analysis (MCDA) are not feasible or practicable. It can also help to better acknowledge the value of ES within financial decision-making processes and to inform budget allocations (de Wit et al., 2012).

3.3 Birmingham Case Study Description and Methodology

3.3.1 Study Area and Scope of Assessment

The administrative boundary of Birmingham covers an area of 267 km^2 and has a population of more than 1 million which is the second highest population of any city in the UK. The area is highly urbanised with a population density of more than 3,700 residents per km^2. Birmingham's green infrastructure is virtually unplanned due mainly to the pattern of historical land acquisition for open space purposes and philanthropic donations and gifts. Overall, Birmingham is characterised by a high degree of surface sealing and comparatively slight and fragmented areas of green space, except for Sutton Park in the north of Birmingham. Nonetheless, 33.7 per cent of the area is green (Sadler et al., 2010). The area of green infrastructure excluding private gardens and water courses adds up to about 6,200 ha which equates to 23 per cent of the total city area.[24] A large amount of greenspace can be classified as amenity grassland which lacks valuation studies applicable to the Birmingham context. The monetary valuation element of the Birmingham Ecosystem Assessment only incorporates 2,100 ha of which broadleaved woodland represents the majority. Therefore, the vast amount

[24] GIS data has been provided by Birmingham City Council, EcoRecord (the ecological record centre for Birmingham and The Black Country) and the UK Forestry Commission.

of green infrastructure in Birmingham remains unvalued in monetary terms mainly due to a lack of applicable primary valuation studies.

Table 3.1 Area of Habitats Evaluated Within the Birmingham Case Study. *Source: Based on data provided by EcoRecord, Birmingham City Council and the Forestry Commission.*

Broad habitat type *Subset*	**Area**	**Area in % of total green infrastructure** *(excl. gardens and water courses)*
Broadleaved woodland	1,528.2 ha	24.7 %
Ancient woodland	*187.2 ha*	*3.0 %*
Wetland	199.2 ha	3.2 %
Floodplain grazing marsh	*190.3 ha*	*3.1 %*
Fens	*7.6 ha*	*0.1 %*
Reedbeds	*1.3 ha*	*0.0 %*
Lowland Heathland	310.3ha	5.0 %
BAP priority grassland	69.6 ha	1.1 %
*Lowland meadows**	*63.2 ha*	*1.0 %*
Lowland dry acid grassland	*5.9 ha*	*0.1 %*
Purple moor-grass and rush pasture	*0.4 ha*	*0.0 %*
* Excluding lowland meadows that is also classified as floodplain grazing marsh to avoid doublecounting.		

Facing further population growth (estimates suggest a population increase of about 150,000 in Birmingham between 2011 and 2031)[25] the pressure on green infrastructure is likely to increase. Therefore undervaluing or neglecting the value of ES may cause a reduction of human wellbeing in Birmingham (Coombes et al., 2010; Grahn and Stigsdotter, 2003; See for example van den Berg et al., 2003; Vries et al., 2003).

The Birmingham Ecosystem Assessment 'Ecosystem Services Evaluation for Birmingham's Green Infrastructure' (Hölzinger et al., 2013b) was published as Appendix 1 of Birmingham's 'Green Spaces Plan' (Birmingham City Council, 2013) which could be labelled as Birmingham's green infrastructure strategy.

[25] 2008-based Subnational population projections by the UK Office of National Statistics.

In the Birmingham Ecosystem Assessment, I assessed the value of as many ES provided by as many broad habitat types as possible; acknowledging budget- and time restrictions. Specific attention was given to non-market ES such as recreation and aesthetical values because these cultural services are very often undervalued or even neglected. The assessment contains qualitative and quantitative elements. As far as possible the value of ES has also been expressed in monetary terms.

3.3.2 Methodology and Stakeholder Involvement

To ensure that the research would be relevant and appropriate for the target audience, a steering group was established at the beginning of the project. This can be seen as a crucial step when implementing research into practice (Daily et al., 2009). The steering group was composed of representatives of different departments of Birmingham City Council and other relevant institutions and stakeholders, such as for example the National Health Service, the Environment Agency, Natural England and local nature conservation organisations and groups. Its aim was to ensure that the most relevant evidence was generated and that the findings were presented in a format that is accessible and applicable. Furthermore, involving several departments and institutions helped to attract greater awareness of the ES concept and related values from the beginning of the project. Therefore, the steering group also had a dissemination role.

A key purpose of the steering group was to determine which ES should be assessed. At a workshop steering group members were presented with a comprehensive list of ES derived from the UK National Ecosystem Assessment framework (UK NEA, 2011a). After a discussion of each ES, participants have been asked to identify the most important ES to be assessed in the Birmingham context.

The stakeholder group identified the following 12 final ES for the assessment: water supply, wild species diversity, recreation, aesthetic values and sense of place, education, economy and employment, health benefits, global and local climate regulation, flood regulation, water quality regulation and air quality regulation. Final ES can be directly 'consumed' by humans; as opposed to supporting services which benefit or underpin these final ES (Atkinson et al., 2012; Boyd and Banzhaf, 2007; UK NEA, 2011a). The purpose of this stakeholder involvement was to avoid a pre-selection of ES which can result in biased outcomes because important values remain 'hidden' as they are not included in the assessment.

The steering group has also discussed which methods should be used to assess the selected ES. Following discussions, the group agreed that the Birmingham Ecosystem Assessment should explicitly address the interrelations between the ecosystem processes and human wellbeing in the urban context; underpinned by local evidence, case studies and where possible monetary valuation.

3.3.3 Non-Monetary Assessment

Following the stakeholder consultation, a mix of qualitative and quantitative evidence was generated for each assessed ES. First, I outlined evidence on how each ES impacts human wellbeing in the urban environment. For the ES local climate regulation, for example, the Urban Heat Island Effect (UHIE), its main drivers such as climate change and development, its effect on human health and wellbeing and how green vegetation mitigates this effect was analysed. Secondly, I presented relevant local evidence and statistics for Birmingham. For local climate regulation evidence about the magnitude of the UHIE, its distribution across Birmingham in correlation to the proportion of green vegetation and the distribution of people at 'high risk' of heat related illnesses was assessed (Tomlinson, 2009; Tomlinson et al., 2011). This local evidence is important to make the value of ES more tangible for the target audience and to show its relevance for decision-making in Birmingham. Thirdly, where possible I calculated the value of ES in monetary terms (see below). In case where a monetary valuation was not possible I assessed the non-monetary element in more detail. Fourthly, policies and institutions relevant to each assessed ES were identified. This was to show that many policies and institutions in Birmingham impact upon and benefit from ES; not only those specifically designed for environmental management and protection. And finally, I made recommendations on how to improve the management of these ES and how decisions affecting them could be better informed. This step included further stakeholder consultations with the aim to identify implementation barriers and reach consensus and approval of the recommendations.

3.3.4 Monetary Valuation

In this section I provide more detail on the monetary valuation element of the Birmingham Ecosystem Assessment. The monetary assessment focused on marginal values. Calculating the marginal value was appropriate for considering the target audience. Decision-makers, for example in planning departments, have to judge marginal land-use changes with marginal impacts on ecosystems and finally the provision of ES. There is no realistic scenario where the whole green infrastructure in Birmingham might be lost to development. The approach applied intentionally led to an under- rather than overestimation of values; I see this as being consistent with academic good practice (see also UK NEA, 2011a).

I did not undertake primary data collection for this study. Existing studies and datasets were used, including transferring values from other valuation studies and study sites to the specific context of Birmingham. Benefit transfer is a practicable and cost-effective way to implement the ES concept in decision-making (Hermann, 2011; Troy and Wilson, 2006), and it is for that reason recommended by the UK Department for Environment, Food and Rural Affairs (Defra, 2007). I undertook a literature review to reveal applicable primary valuation studies. Priority has been given to recent studies which have been undertaken in the UK. Where possible I made adjustments regarding site-specific conditions and socio-economic variables to reduce the transfer-error.

One mistake often made when valuing ES is double counting (Hein et al., 2006; Turner et al., 2003). The risk is even higher when valuing such a wide range of services as well as different habitats as in this Birmingham case study. The ecosystem interactions as well as the relations between different services are characterised by high complexity. Therefore, I paid considerable attention to this issue and only valued final ES.

The uncertainties and limitations of the benefit transfer approach (e.g. transfer errors) and primary valuation techniques necessitate the use of sensitivity analysis. Using sensitivity analysis every valued ES has been stated as a ‘best guess’ with a range. It should also be noted that the values are gross rather than net values. Neither alternative land-use options nor the costs of land management and the like have been considered.

The values of ES are not only stated as annual values but also as capitalised value over 50 years. To calculate the Net Present Value (NPV) of future benefit it is common to apply a discount rate, although I acknowledge that this practice is controversial (see e.g. Bingham et al. 1995; Stern 2006; Sáez & Requena 2007; German Federal Environment Agency 2008; Perino et al. 2011). A discount rate was used to convert future benefits to present values to make them comparable over time. I applied a discount rate of 1.5 per cent to calculate the 'best guess' values. For the upper threshold of the sensitivity analysis I applied a discount rate of 0 per cent. For the lower threshold I applied the discount rate recommended by HM Treasury. HM Treasury recommends a discount rate of 3.5 per cent for periods of up to 30 years. After 30 years this rate declines to 3.0 per cent (HM Treasury, 2003).

For capitalised values I implied a *ceteris paribus* future. This assumption states that all variables are set constant over time. Neither the assumed population growth in Birmingham nor the additional pressure caused by climate change has been considered in the capitalised value. Both effects can be expected to increase the values of ES over time.

One concern expressed by steering-group members was related to the potential misinterpretation and misapplication of monetary values. Especially because such monetary values do not cover the whole value of ES the concern has been expressed that such evidence may be used to 'sell the environment'. This is not a worry only related to the Birmingham context (Bingham et al., 1995; Turner et al., 2003). To address this concern I stressed in the main report that values should not to be confused with market prices and that monetary values only represent a baseline figure rather than a comprehensive total value (Hölzinger et al., 2013b). Notwithstanding this concern, the steering group agreed that the use of monetary values would be best accessible for the target audience (See also Balmford et al., 2005; Burkhard et al., 2012; Daily et al., 2009).

As the majority of evaluated green infrastructure within scope of this case study is woodland, particular attention has been paid to this habitat category. I applied three woodland related primary valuation studies for a benefit transfer. To calculate the annual 'wild species diversity' value of woodland in Birmingham I multiplied the mean willingness to pay (WTP) for woodland in the UK elicited by Hanley et al. (2002) by the number of households in the West Midlands assuming that mostly residents in the West Midlands Region benefit from woodland in Birmingham as 'habitat for species'.

To value the recreational benefits of woodland in Birmingham a benefit transfer of the findings of Scarpa (2003) has been applied. First, I estimated the average number of annual visits to woodland undertaken by Birmingham residents using 'Monitor of Engagement with the Natural Environment' (MENE) data provided by Natural England. Then I multiplied this number by the average WTP per visit to access a local woodland site (Scarpa, 2003).

To calculate aesthetic values of Birmingham woodlands I transferred the findings from Garrod (2002) who valued the WTP for woodland views from home, applying the stated preferences method. I estimated the number of households with such a view on woodland by creating buffers around the urban woodland in Birmingham and then estimating the number of households within these buffer zones with a free view on woodland sites using Ordnance Survey Address Point GIS data (residential only).

I valued wetlands in Birmingham through a benefit transfer of the findings provided by Brander et al. (2008) who carried out a meta-analysis of 78 European studies. This allowed us to calculate the ES flood risk regulation, water quality regulation, surface and ground water supply, biodiversity, recreation and amenity and aesthetic services.

I also valued ES provided by BAP priority habitats not evaluated above with the aid of a primary valuation study undertaken by Christie et al. (2011) and recalculated the figures for the purpose of this investigation.[26] This enabled the calculation of flood regulation, wild species diversity and cultural services provided by heathland and several BAP priority grasslands. Detailed valuation methods and calculations can be reviewed in the main report 'Ecosystem Services Evaluation for Birmingham's Green Infrastructure' (Hölzinger et al., 2013b).

[26] The aim of that study was to estimate the value of changes in biodiversity and associated ecosystem services which would result directly from the delivery of the UK Biodiversity Action Plan (UK BAP). The aim of the UK BAP is to describe UK's biological resources and to provide conversation plans to mitigate the loss of biodiversity. Specific objectives of the study were to assess the marginal value of ecosystem services per habitat associated with the UK BAP and the marginal value of conservation activities associated with different scenarios.

3.4 Results

The main outcome of the Birmingham Ecosystem Assessment was that ES provided by Birmingham's green infrastructure are of particular importance and value to the cities' population. Drivers like climate change and the projected population growth (including additional housing and infrastructure demands) are likely to put additional pressure on ecosystems and the services they provide. At the same time the growing population also increases the (total) human demand for ES. This may result in a decline of ES and finally of the (per capita) wellbeing for the city's population if the value of ES will not be better taken into account when making decisions affecting ecosystems. This is not only an isolated task for institutions specifically dedicated to environmental management such as Birmingham's parks and nature conversation department; it is a cross-sectorial issue and necessitates cross-sectorial action.

Stating the best estimate, the habitats in Birmingham evaluated in monetary terms within scope of the Birmingham Ecosystem Assessment were valued at £11.7 million annually or £420.5 million capitalised over 50 years (2011 prices).[27] As mentioned previously, the scientific basis reveals large data gaps which lead to a general undervaluation. Furthermore, most of the ES which have been given a monetary value are still likely to be undervalued. Therefore, the findings should be treated as lower bound estimate of the real value. Table 2 provides an overview of the ES that have been valued in monetary terms. More detailed findings and the results of the sensitivity analysis can be reviewed in (Hölzinger et al., 2013b).

[27] Applying a discount rate of 1.5 per cent.

Table 3.2 Annual value of ecosystem services provided by Birmingham's green infrastructure.

<table>
<tr><th colspan="2">Best guess estimates; annual values; 2011 prices</th><th>Woodland</th><th>Heathland</th><th>Wetland</th><th>BAP Priority Grassland</th><th>Total</th></tr>
<tr><td rowspan="2">Provisioning Services</td><td>Water Supply</td><td></td><td></td><td>£0.001m</td><td></td><td>£0.001m</td></tr>
<tr><td>Wild Species Diversity</td><td>£0.25m</td><td>£0.19m</td><td>£0.10m</td><td>£0.03m</td><td>£0.64m</td></tr>
<tr><td rowspan="3">Cultural Services</td><td>Recreation</td><td>£1.42m</td><td rowspan="3">£0.65m</td><td rowspan="2">£0.10m</td><td rowspan="3">£0.10m</td><td rowspan="3">£10.13m</td></tr>
<tr><td>Aesthetic Values & Sense of Place</td><td>£7.78m</td></tr>
<tr><td>Cultural Heritage & Spiritual Values</td><td></td><td></td></tr>
<tr><td rowspan="3">Regulating Services</td><td>Flood Regulation</td><td>£0.76m</td><td>£0.10m</td><td rowspan="2">£0.10m</td><td>£0.01m</td><td rowspan="2">£0.98m</td></tr>
<tr><td>Storm Buffering</td><td></td><td></td><td></td></tr>
<tr><td>Water Quality Regulation</td><td></td><td></td><td>£0.08m</td><td></td><td>£0.08m</td></tr>
<tr><td colspan="2">Total</td><td>£10.20m</td><td>£0.94m</td><td>£0.38m</td><td>£0.14m</td><td>£11.66m</td></tr>
<tr><td colspan="2">Area of Habitat</td><td>1,528 ha</td><td>310 ha</td><td>199 ha</td><td>70 ha</td><td>2,107 ha</td></tr>
<tr><td colspan="2">Average Value per Ha</td><td>£6,678</td><td>£3,034</td><td>£1.904</td><td>£2,005</td><td>£5,536</td></tr>
<tr><td colspan="7">Notes: All values are 'best guess' estimates. Cells left blank can't be interpreted as 'no value'.</td></tr>
</table>

The summary Table only covers ES where it has been possible to value at least one habitat. The unvalued services are considered to provide benefits as well and this has been assessed in non-monetary terms but a lack of information did not allow the valuation in monetary terms within scope of this investigation. Furthermore, it should be acknowledged that for some ES only an element of the total benefits to human wellbeing has been valued in monetary terms. For woodland, for example, only the value of a free view on woodland from home has been valued. However, the aesthetic values and sense of place provided by woodland includes a wide range of elements of which the woodland view from home is just one component. It should also be emphasised that the high average per-hectare values for woodland compared to other habitats must not be interpreted as 'woodland is more valuable than other habitats'. Different approaches have been used and different ES have been valued which complicates a comparison between the per hectare values of different habitat types.

The project steering group agreed, based on the findings of the Birmingham Ecosystem Assessment, that departments and institutions affecting ecosystems in Birmingham need to work better together to achieve common goals such as enhancing human wellbeing by jointly managing ES. The steering group agreed for example that more evidence about the impacts of different sectors and institutions on ES is demanded and that the application and development of tools to better implement the value of ES in decision-making at the project scale are necessary. One concrete recommendation was to develop a planning tool for Birmingham to better assess and manage the impacts of proposed developments and spatial plans on the provision of ES. The development of such a tool is in progress. Better information sharing and knowledge transfer would also be necessary to enable institutions which are usually not engaged in environmental management to implement ecosystem values in their decisions and policies.

3.5 Discussion

In this section we explore the mismatch between ES related evidence provided by the scientific community and the type of evidence desired by relevant decision-makers at the municipal scale. We show how the Birmingham case study illustrates routes to overcome some of these issues and draw some recommendations for how the demand for relevant evidence can be better provided by the research community. Furthermore, we discuss how municipal Ecosystem Assessments relate to project level tools like Multi-Criteria Decision Analysis (MCDA) and Cost-Benefit Analysis (CBA) and when and why monetary valuation can be helpful to support decisions.

3.5.1 The Mismatch Between Demand and Supply of Ecosystem Services Evidence

On the one hand there is clear evidence of a growing interest from decision-makers for valued ES, including government agencies and local authorities. On the other hand, we are currently seeing a rapid evolution of ES relevant research, evidence and tools. But the implementation of such evidence into decision-making remains fraught with difficulties. One reason for that is a mismatch between evidence provided by the scientific community and evidence demanded by local decision-makers who deal with decisions affecting ecosystems, for example land-use changes. Moreover, scientific evidence is often difficult to access for local decision-makers. There is a gap between the scientific community as provider of evidence and governmental institutions requiring such evidence.

We can identify several reasons for this. First, the flow of ES is often insufficiently characterised in biophysical and economic terms at the local and regional scale where it is most useful for decision-makers (Chan et al., 2006; Turner and Daily, 2008). Secondly, the scientific community has not always communicated findings to the decision-makers with sufficient clarity and impact (Fisher et al., 2009; Turner et al., 2003). Thirdly, there is still considerable work needed to evaluate the importance of the assessment scale and the important role played by governmental institutions and actors. Fourthly, there are clear gaps in the evidence available to enhance policy formulation.

Research findings are often not presented in a format that can be easily accessed by decision-makers:

> *"Since policy-makers do not typically revisit policies for their relevance to the latest scientific findings, it is important to make scientific practice self-aware in a policy-relevant way."* (Shi, 2004, p. 29)

An additional barrier is the topic-specific terminology used within academic publications and the necessary time-effort for the decision-maker to identify relevant information. Findings are usually not presented in a 'fit-for-purpose' format and demand comprehensive re-evaluation and interpretation which often cannot be provided by governmental institutions, especially at the local level.

ES are often valued at a plot, site, or habitat scale (Hein et al., 2006). Whilst scientists tend to undertake primary valuation research at small homogeneous study sites, decision-makers demand more generalised information and evidence which can be implemented over a broad range of decision-making contexts and large geopolitical regions (Shi, 2004). Especially for small-scale decisions at the local level it is usually not feasible and efficient to undertake expensive and time-consuming primary valuation studies; for example to inform Cost-Benefit Analysis. Furthermore, scientists often select ES for valuation studies because they are comparatively easy to value and corresponding data is available, rather than because they are most important for the decision-making context. The ecosystem valuation literature reveals very few studies where a broader range of ES have been valued (Turner et al., 2003). But usually the policy-options of the decision-maker do not affect one isolated ES - such decisions affect sites, habitats, or catchment areas and thus encompass a broad range of ES. Evidence and values for a single ES are not very useful in such a context. The decision-maker demands evidence about the value of all ES affected by a decision to be able to reveal and judge trade-offs and to make a well-founded decision.

3.5.2 A Matter of Scale: Closing the Gap Between (Inter)national and Project-scale Assessments

Decisions affecting ecosystems are made at all institutional hierarchy levels from the international to the individual level (Hein et al., 2006). In the United Kingdom, the National Ecosystem Assessment (UK NEA, 2011a) aimed to inform high-level decision-makers and institutions about the value of UK's ecosystems and its importance for human welfare. However, the relevance to local decision-makers considering their everyday circumstances is limited because findings cannot easily be downscaled to an appropriate scale. It is the case that such broad-scale assessments cannot be sufficiently rationalised and operationalized at the local level (see also Chan et al., 2006). Providing evidence and defining goals at the national and international level is an important step, but such strategic objectives must be accompanied by evidence, tools, and effective institutional response at the local level to actually effectuate such goals.

Many different institutions and actors at different levels influence local decision-making affecting ecosystems, for example planning decisions (Muradian and Rival, 2012). Usually there is national legislation and policy which is sometimes based on transnational directives or international commitments. However, such national policy and legislation is formulated in a more general manner and has to be made concrete when implemented at the local level. Local decision-makers have considerable creative license to interpret and reshape such high-level policy. Land-use change and the management of land have a great impact on the sustainable provision of ES. There is a remaining requirement to better inform decision-makers at the municipal scale about the value of ES and the trade-offs inherent in many decisions affecting ecosystems (Primmer and Furman, 2012; Turner et al., 2003).

Whilst the development of project-specific assessments, e.g. to inform Multi-Criteria Decision Analysis, may be appropriate for large-scale developments, the everyday work of the decision-makers, e.g. within local planning authorities, is dominated by small-scale proposals such as the development of few dwellings. Decision-makers usually have very limited resources to inform themselves about the value trade-offs inherent in such decisions. Expensive and time-consuming project-specific primary research evaluating the change of ES by such developments seems not practicable and efficient. Therefore, more general evidence about the value of ES is demanded to serve decision-makers in their everyday-work. ES relevant information must be available in a format that can be understood and operationalized by the decision-maker; and at a scale where the decisions take place.

I acknowledge that for many decisions affecting ecosystems the application of tools like Multi-Criteria Decision Analysis (MCDA), an extended Cost-Benefit Analysis (CBA), or a combination of both (Barfod et al., 2011), would be the preferred option. The main advantage of applying for example MCDA at the project level is that it helps to deal with complex trade-offs by integrating multiple and heterogeneous dimensions and criteria of which the impact on ES is just one element. Another advantage is that different policy options are compared and that marginal changes rather than total values are assessed which is more useful to judge and select a preferred policy option. When applying MCDA, it is possible to assign for example relative weights to different (sets of) indicators to compare them and to reveal trade-offs. Monetary valuation for some of these indicators is possible, but not necessary (Kiker et al., 2005; Koschke et al., 2012).

Notwithstanding the advantages of applying tools like MCDA to support decisions affecting ecosystems, for many of such decisions they are rarely applied (Kiker et al., 2005). This has different reasons. First, the complexity of such decisions demands the implementation of several information sources (including stakeholder and expert opinions) and indicators which are often coming from diverse sources and not provided in a consistent and easily accessible format. This makes it difficult for decision-makers to implement such criteria in their decisions. Secondly, for many small-scale decisions, such as planning decisions about the development of few dwellings, it is often not efficient and feasible to generate comprehensive project-specific evidence. Thirdly, decision-makers at the local level are often not equipped with the necessary financial and personnel resources as well as technical skill sets to apply tools like MCDA more widely.

Whilst some of these obstacles may be resolved in the future one has to acknowledge that this is probably a longer process and not applicable for many small-scale decisions. In this respect city-wide Ecosystem Assessments (and municipal Ecosystem Assessments in general) can be seen as a second-best solution to better acknowledge the value of ES in local and project-level decision-making; not least by just making the decision-makers aware of such values.

The aspiration of this study was not to provide a comprehensive (monetary) value that covers the total value of all ES provided by all ecosystems in Birmingham, but rather to see how far I could get with data that was readily available. This analysis shows that there is sufficient data available to make significant progress with urban ES valuation in a (UK) urban setting, through desk-based study alone. However, we must also acknowledge the shortcomings. Many required statistics and baseline data were not available for the area examined. Even basic data about the extent of the habitats were incomplete and inconsistent with reference to different sources. Gaps in scientific evidence included general uncertainties about ecosystem functions and interactions; limitations to primary valuation methods; and potential benefit transfer errors (see also Bingham et al., 1995; Fisher et al., 2011; Hermann, 2011). Clearly these are areas for future studies to address.

Even if the applicability of the Birmingham case study findings is limited by the above data gaps, it still provides decision-makers with a magnitude of the value trade-offs inherent in such decisions, highlights opportunity costs and reveals stakeholder interests in an accessible manner.

Urban ES assessments should seek to improve the information basis related to the status quo, acknowledging that evidence will always remain inadequate to assess every single situation in which ecosystems are affected. It also reveals the measures that are available to support decision-making at the project scale. Municipal Ecosystem Assessments have the potential to better inform tools like MCDA and CBA by providing relevant proxy-values and proxy-criteria; especially when project-specific criteria cannot feasibly be established as part of the decision-making process. Not least, municipal ecosystem assessments may also encourage the application of tools such as MCDA by highlighting the high complexity of decisions affecting ecosystems as it was the case in Birmingham.

3.5.3 Impact and the Way Ahead

Assessments such as the Birmingham case study should not be seen as a one-off project; rather it should be seen as a stepping stone towards better situating externalities into decision-making at the municipal level leading to better informed decisions. During the engagement and discussions with different departments of Birmingham City Council, but also other relevant institutions as part of the steering group engagement, we observed that the ES concept receives much awareness and approval. It also engages the discussion and initiation of new practical opportunities of applying the ES concept to support decision-making. The project has raised considerable awareness in the West Midlands region (the area round Birmingham) and beyond. The recent commissioning of an Ecosystem Assessment by Staffordshire County Council and Warwickshire Wildlife Trust and ongoing discussions with other local authorities and NGOs, demonstrates that there is a clear demand for Ecosystem Assessments and ecosystem valuation at the local and regional scale.

The Birmingham case study can be seen as a knowledge transfer method to utilise the best available evidence. Such methods have an important role to play since decisions affecting ecosystems are taking place here and now, by local and regional authorities who are interested in new tools to inform these decisions, but have neither the time nor the resources to gather the kind of detailed evidence that would feed the best available academic models. Real-world problems are not waiting for improved science; they have to be dealt with now with currently available data, converted into information that is actionable and 'decisive' (Bingham et al., 1995).

This means that we have to gain a better understanding of how evidence is perceived by decision makers and how it is actually impacting (or not) on real-world decisions. It would be naive to assume that the only incentive of decision-makers and bureaucrats would be to maximise human wellbeing. A more realistic assumption is that actors within governmental institutions have their own incentives and pursue individual goals, such as for example winning the next election or maximising their individual power (see e.g. Hölzinger, 2010; Ménard and Shirley, 2005; Williamson, 1983). Therefore, I conclude this discussion with a call for demand-driven, bottom-up research, acknowledging the function of political and bureaucratically institutions including the incentive structures and everyday circumstances (expertise, time constrains, etc.) of their actors.

3.6 Conclusions

Assessments where ES have been evaluated in monetary terms have been undertaken at the global and national scales (Costanza et al., 1997; UK NEA, 2011a). Such Ecosystem Assessments have raised considerable awareness of the value and continuing loss of ecosystems and ES – not just within the academic community, but also in policy arenas (Hermann, 2011). However, the next step to implementing such advanced measures and evidence into real-world decision-making is still in its infancy, even if some examples are available (see e.g. TEEB, 2010b for an overview).

In this paper I have discussed barriers that inhibit a better implementation of the ES concept and valued ES relevant for 'real-world' decision-making at the municipal and local level. I showed that relevant information is often not provided in the right format and at the right scale where it would be most useful for these decision-makers. One major problem is that in decision-making often not the most critical objectives are taken into account which can lead to biased and poor decisions (Bond et al., 2008). Ecosystem valuation can mitigate this problem by making the magnitude of complex ecosystem coherences visible and tangible. It provides relevant information in a format decision-makers are familiar with. Monetary values can serve as a common denominator to better judge value trade-offs, especially when advanced tools like MCDA are not applicable. One has to acknowledge that ecosystem processes and the links to human wellbeing are often very complex and decisions affecting ecology are frequently not made by ecological experts. Through monetary valuation, the very complex coherences between ecosystems and human welfare are reduced to one metric which can be operationalized by those who have to make regular decisions affecting ecosystems but who are not professionals in ES research. This is notwithstanding that other criteria which cannot be valued in monetary terms should be taken into account as well.

The presented Birmingham case study shows that the benefit transfer approach can be used to provide information at the right scale and to reasonable costs. Stakeholder involvement throughout the whole research process helped to provide the information that is most useful in their view and to ensure that the information is presented in a format that can be assimilated by the predominantly non-academic target audience. The challenge for the research community is to participate in demand-driven research in a close collaboration with the target audience, using creatively the limited data that is at hand and yet guarding the academic quality of the research, in terms of best practice and fit for (a particular decision making) purpose.

4 Chapter Four: Birmingham Natural Capital Accounts and Health Economic Assessment[28]

4.1 Abstract

In this chapter, I present Natural Capital Accounts (hereafter NCAs) and a Health Economic Assessment to reveal the social value of parks and greenspaces managed by Birmingham City Council; expressed in monetary terms. Birmingham City Council manages an area of over 4,700 ha of parks, greenspaces and allotments. The assessment covers the following ecosystem services (hereafter ES) and benefits: property value uplift, Council Tax uplift, physical health benefits, mental health benefits, air quality regulation, recreation, climate regulation, food production (via allotments), biodiversity and flood risk regulation. Using a benefit transfer approach, this assessment reveals that the total net asset value of Council-managed natural capital (hereafter NC) is in the order of £11 billion over 25 years or £594 million annually. This means that the estimated gain using this valuation approach is of a return of £24 for each £1 the Council spends on parks and greenspaces.

The assessment also shows that, from a Council finance perspective only, NC is a net-asset worth £270 million over 25 years. This is because the presence of Council-managed parks and greenspaces increases the annual Council Tax income by approximately £28 million due to the greenspace-related property value uplift (in addition to direct parks income of £13 million). In contrast, the Council only spends about £26 million on its Parks Services every year. To my knowledge this is the first time Council Tax uplift due to NC has been calculated.

This assessment contributes 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. And indeed, based on Birmingham City Council's conventional accounts, Council-managed parks and greenspaces are accounted for as a net-liability rather than a net-asset. This suggests that relying on

[28] The content of this Chapter was previously published as a research report: Hölzinger, O., Grayson, N., 2019. Birmingham Health Economic Assessment & Natural Capital Accounts. Birmingham City Council, Birmingham. The content of this report was amended and updated to be suitable for inclusion in this thesis. The co-author listed above provided only editorial comments.

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 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 these findings, I posit that green infrastructure of which Council-managed parks and greenspaces form part, should be seen as critical infrastructure rather than just a 'good to have'.

4.2 Introduction

4.2.1 Background

It is increasingly recognised worldwide (Millennium Ecosystem Assessment, 2005; TEEB, 2010a) and in the UK (ONS and Defra, 2017; UK NEA, 2011a) that better valuation and accounting of NC is a requirement for its protection and enhancement.

Gross Domestic Product (GDP) is commonly seen as the flagship indicator for national accounting. However, despite widespread public perception, it is not a measure of welfare but rather a measure of the flow of economic activity in a given time period. Crucially, it commonly omits non-market goods and services (including many ES) as well as (natural) capital stocks (Badura et al., 2017). NC 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 NC is called ES 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 4.1 for an overview).

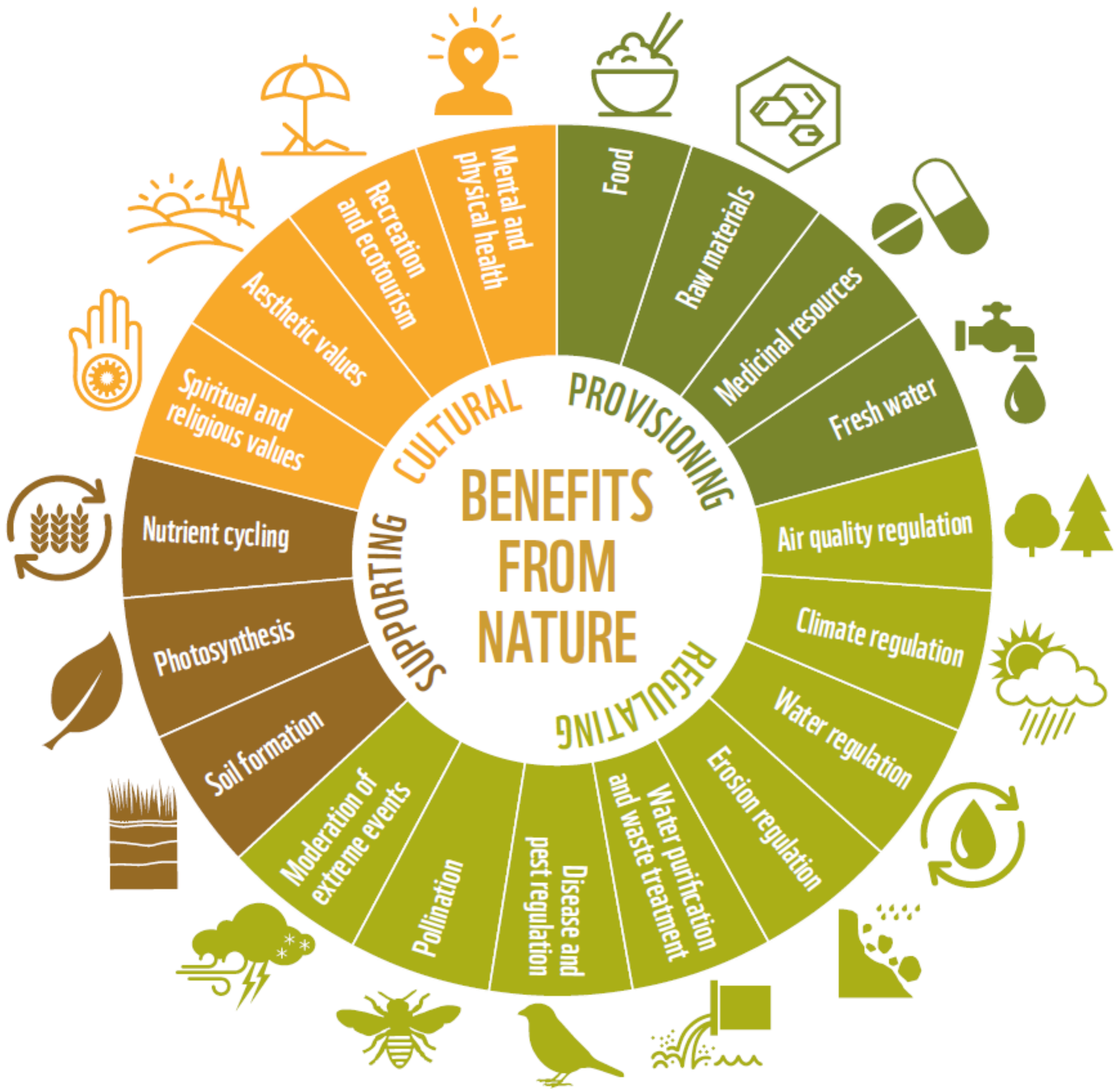


Figure 4.1 Ecosystem Services Overview. The figure shows a selection of ecosystem services which are commonly categorised into cultural-, provisioning, regulating and supporting services. *Source: WWF (2018), p. 19.*

A major step towards integrating NC and ES into national accounts was the development of the first System of Environmental-Economic Accounting (SEEA) (European Commission et al., 1993). This was a collaborative initiative by the European Commission (EC), the International Monetary Fund (IMF), the Organisation for Economic Co-operation and Development (OECD), the United Nations (UN) and the World Bank to set out a framework to guide the compilation of consistent and comparable statistics integrating environmental-economics accounting for their member states which has been subsequently updated (UN et al., 2014).

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). This commitment is in line with Target 2 of the EU Biodiversity Strategy to 2020, 'maintain and restore ecosystems and their services', which states:

> *"The strategy proposes that a strategic framework be developed by Member States, assisted by the Commission, to set priorities for ecosystem restoration at EU, national and subnational level by 2014. It will be supported by work to map and assess the state of ecosystems and their services, and* ***to better integrate the value of ecosystem services into national and EU accounting and reporting systems****."* (European Union, 2011, p. 14)

In the academic literature, calls have been made for quite some time to better integrate the value of NC and ES into accounting and decision-making (see for example Costanza et al., 1997). As a response to the NEWP, the Natural Capital Committee was established in 2012 to provide independent advice to the UK Government on the sustainable use of the nation's NC. In its first State of Natural Capital Report, the Committee stated:

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

The Office for National Statistics (ONS) also published a roadmap which set out a strategy to incorporate NC into UK Environmental Accounts by 2020 (ONS, 2012) and subsequently developed national NCAs for different habitat and asset types (ONS, 2019a). The ONS defines NCAs 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)

Progress towards developing national NC accounts in the UK (ONS, 2019a; Sunderland et al., 2019) and for example EU member states (Ling et al., 2018) is clearly evidenced. It is arguable, however, that despite the progress made in UK national NC accounting, NCAs are also required at the local and regional level to inform for example Council budget decisions and management decisions affection local parks and greenspaces. Despite emerging examples for local NCAs in London (Vivid Economics, 2017) and Greater Manchester (Eftec, 2018), local NCAs are still rare in the UK.

Birmingham City Council, who commissioned the work presented in this chapter, has taken on a pioneer role in applying advanced methods to assess the value of NC and ES. In 2013, the Council published its Green Living Spaces Plan highlighting the value of ES provided by the city's green infrastructure (Birmingham City Council, 2013; Hölzinger et al., 2013b).

In 2015, Birmingham City Council commissioned the University of Birmingham to further refine NC values to better inform the Council's decision-making and reporting by setting up provisional NCAs for the Council's parks and greenspaces (Hölzinger and Sadler, 2016); to my knowledge the first city-wide NCAs in the UK. Building on this pioneering work, these accounts have been updated and expanded to capture as much of the value Birmingham's parks and greenspaces provide to people as possible.

Crucially, this also includes the valuation of health benefits provided by Birmingham's parks and greenspaces (Section 4.3.2). 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 NC is associated with a wide range of positive health effects (Tzoulas et al., 2007). This, in turn, is thought to help prevent the onset of diseases such as obesity, diabetes, heart diseases and strokes (reviewed in Sadler et al., 2010).

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 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) also 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 be correlated with reduced mortality (Defra, 2017).

As public health is constantly high on the political agenda in the UK and in Birmingham, particular attention has been paid to quantifying the health benefits of Birmingham's NC assets; 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 NC (see Defra, 2017 for an overview). It should also be noted that almost all ES provided by NC have some impact on human health (Figure 4.2).

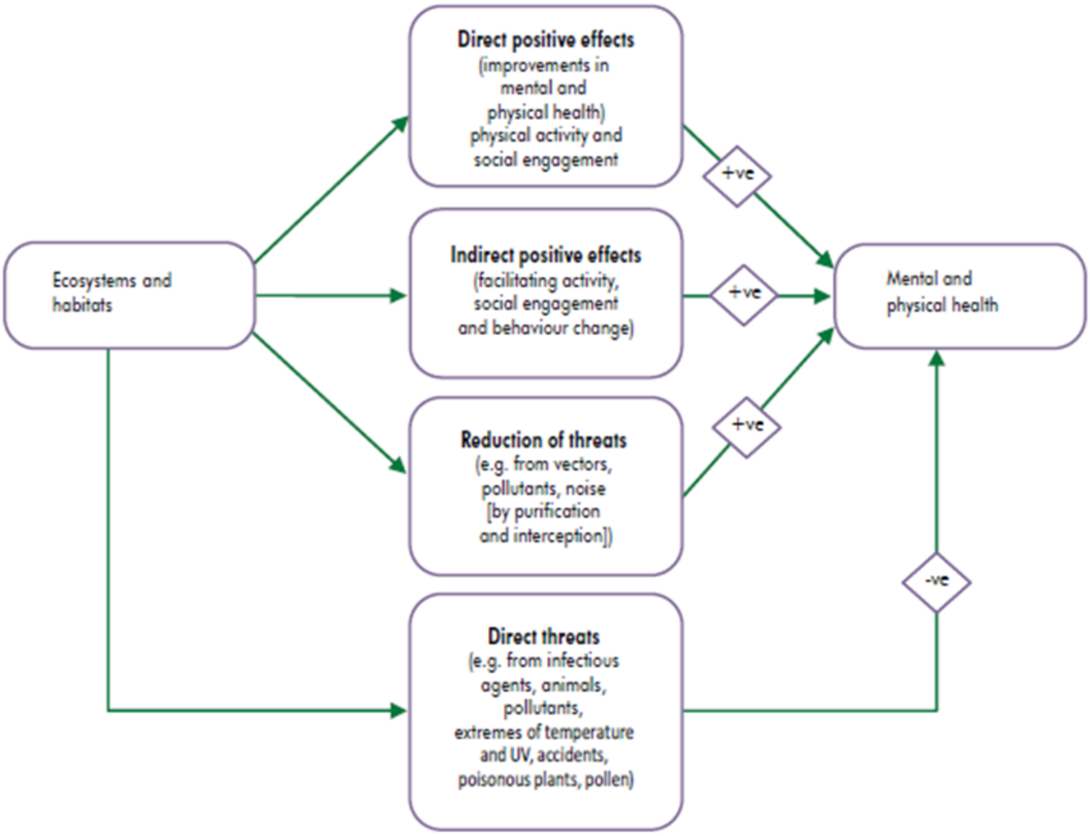


Figure 4.2 Health Benefits and Threats from Ecosystems. The figure summarises how ecosystems contribute positively to health through direct and indirect positive effects such as providing space for physical activity as well as reduction of threats such as from pollutants on the one hand. On the other hand, they can also have negative effects such as through poisonous plants. *Source: 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 ES. This is in line with the definition of health by the World Health Organisation (WHO):

> *"Health is a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity."*

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

4.2.2 Aims and Objectives

Conventional financial accounts only tell part of the revenue story because 'external' benefits provided by NC 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, for example.

The costs for planting and managing forests, however, is usually included in conventional accounts which can leads to the false assumption that NC is mainly a liability rather than a valuable asset.

The main aim of this study was to calculate the economic net-NC value of all parks and greenspaces managed by Birmingham City Council.

The objectives were to:

1. Establish physical accounts for NC stocks over which Birmingham City Council has stewardship responsibility and the ES that flow from them;
2. Calculate the economic value of these NC assets, including health benefits; and
3. Integrate these 'external' NC values into Birmingham Parks Department accounts.

4.2.3 Geographical Scope: Council-managed Natural Capital Assets

The geographical scope of this assessment is determined by NC 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 NC assets such as gravel or gas reserves. The scope of this assessment is limited to green infrastructure NC assets only. These NCAs 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 just outside the city boundaries towards the south-west (Figure 4.3). Such areas are still included in the assessment scope of this investigation as they are a key city asset.

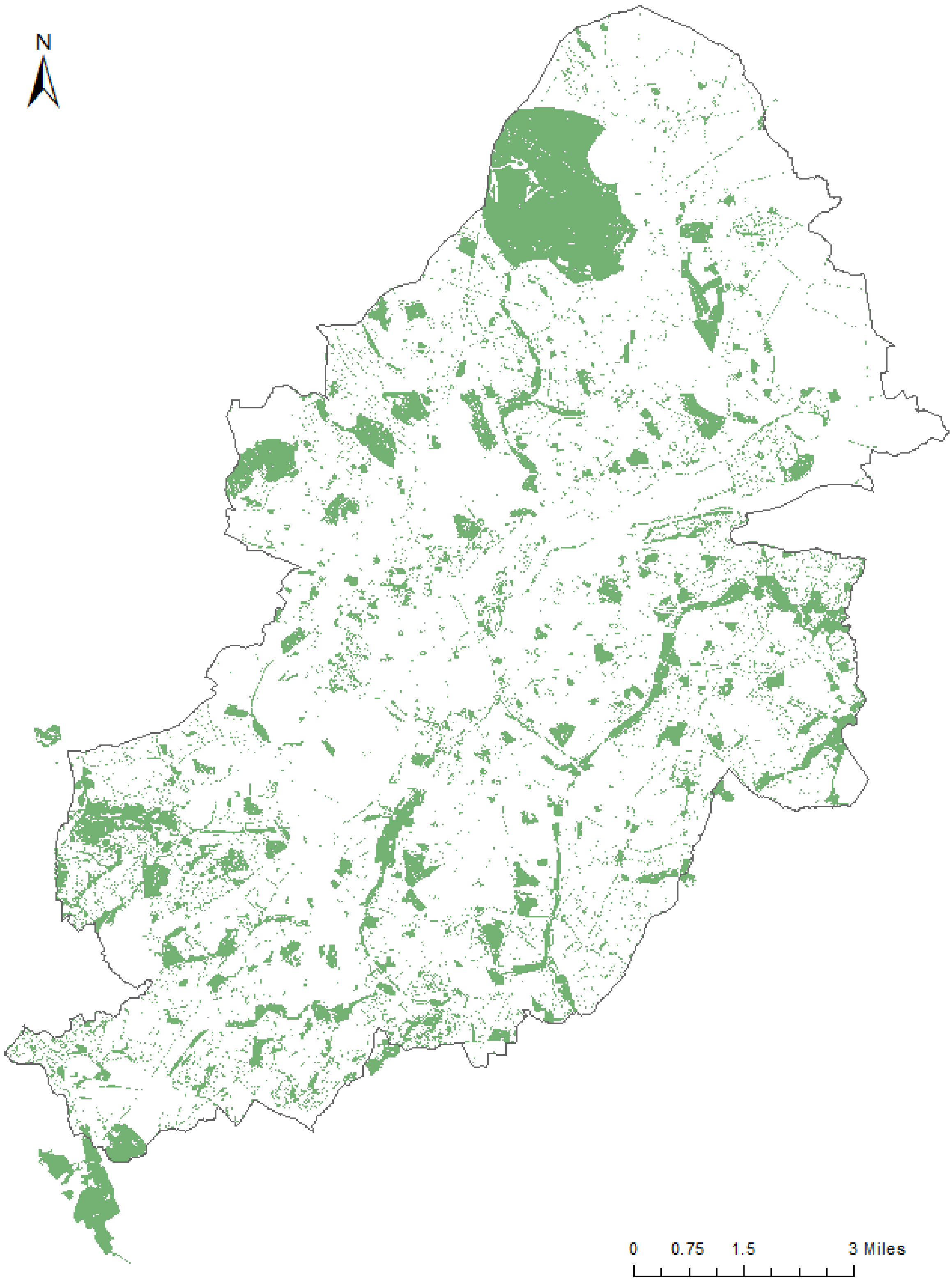


Figure 4.3 Geographical Assessment Scope. The figure shows all NC assets assessed within scope of this study. More information about the area and habitat composition is provided in Table 4.1. *Source: Based on data provided by Birmingham City Council, Natural England, the Forestry Commission and EcoRecord.*

Birmingham City Council has a good record of all the NC assets it maintains directly through its Parks Services. All data are 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 (Natural England, 2019a) and Priority Habitat Inventory (Natural England, 2019b), the Forestry Commission's National Forest Inventory (Forestry Commission, 2019), and habitat data provided by EcoRecord, the local environmental record centre for Birmingham and the Black Country.

Altogether, an area of 4,745 ha was included in the assessment scope totalling about 17.7% of Birmingham's land area. The main NC asset types included in this assessment were grassland (2,684 ha), woodland (1,068 ha) and heathland/shrub (536 ha), although I also included 259 ha of allotments. NC 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 4.1. Following, these habitats are described as NC to highlight their asset character.

Table 4.1 Area of Assessed Broad Habitat Types and Corresponding Sub-habitats for Birmingham. *Source: Author calculations based on data provided by Birmingham City Council, Natural England, the Forestry Commission and EcoRecord.*

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**

4.3 Methodology

4.3.1 Methodical Approach & Limitations

When developing these NCAs, particular attention was 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 NCAs for the UK produced for Defra (Eftec, 2017). It should be noted that NC accounting at all geographical scales is still a developing area of research and a consistent approach for developing NCAs has not yet emerged (Edens and Hein, 2013). The NCAs for Birmingham contribute to the research field.

For this assessment, the Total Economic Value (TEV) approach was chosen as a measure of the net value NC provides to society. This needs to be distinguished from an economic impact assessment, which is a measure of economic activity, such as GDP. Employment wages to manage NC, 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 NC value assuming that without that management the greenspace would not perform ecosystem services to the extent it does with management.

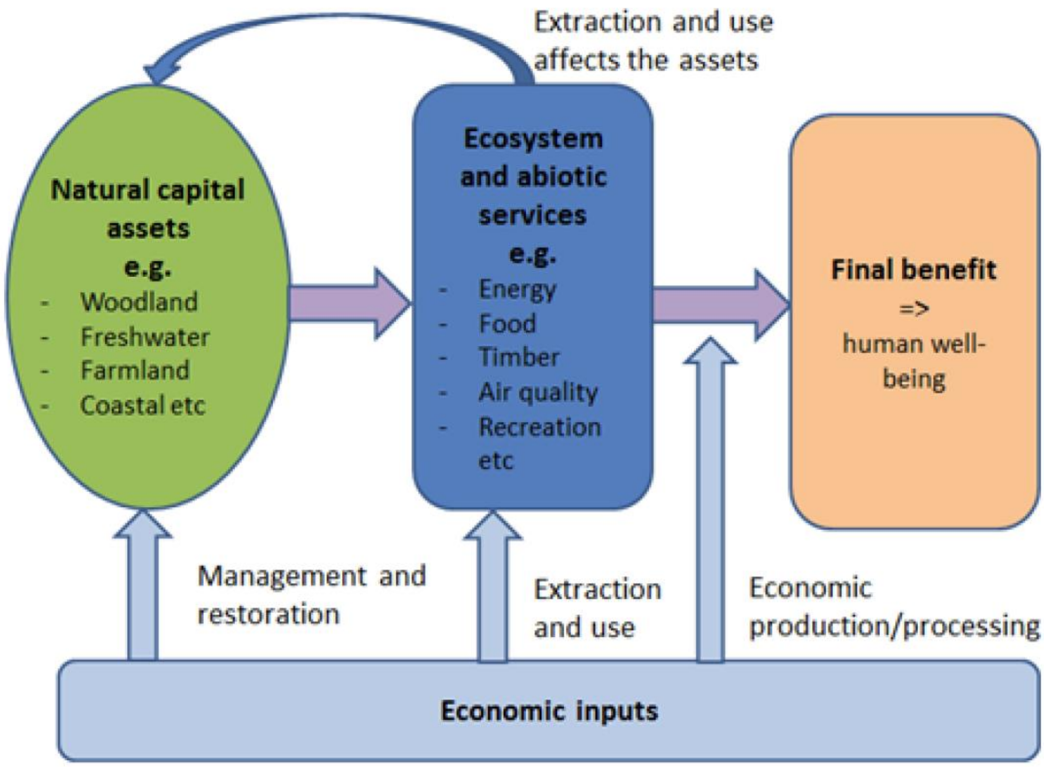


Figure 4.4 The Links Between Assets, Services and Final Benefits. The figure summarises in simple terms how accounting is based on a rigorous distinction between the asset or stock (left hand side) that generates a flow or service (net of human and other economic inputs); this service may then be further processed in some way before its final use or consumption. *Source: ONS and Defra (2017), p. 4*

The benefit transfer approach (e.g. Defra, 2007) was used to quantify NC and ES values in monetary terms. Valuation evidence from research carried out elsewhere or for example at the national scale were transferred to the assessment area applying suitable precautions and assumptions as outlined below. Where possible, adjustments regarding context-specific circumstances and socio-economic variables such as population density have been made to minimise potential transfer-errors. It was not possible to undertake original primary valuation studies 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).

Given the issues identified above, it is important to list the limitations and caveats surrounding the use of this approach. For example, related Willingness-To-Pay (WTP) techniques applied in primary valuation studies are subject to social desirability bias[29] or a

[29] The interviewees may suggest that they value an ecosystem service more than they actually do.

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 NC) 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 (Bateman et al., 2011).

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 indicative:

> *"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)

A sensitivity analysis was applied to take uncertainties into account within this investigation. 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 calculated (such as the value of carbon stored in vegetation and soils). Where benefits are occurring as an ongoing service flow through ES such as for recreation, monetary values are stated both, as annual and capitalised values. Capitalised values 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 was chosen to align 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 NCAs (ONS and Defra, 2017).

A discount rate was applied to calculate the 'net present value' of future benefits. It is used to convert future benefits (and costs) to present values making them comparable over time. For the purpose of this investigation, a discount rate of 3.5% was 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%[30]:

> *"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).

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 assumed constant over time.

It should also be acknowledged that 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 NC assets and their ES and benefits. And even if values were calculated for an ES, they may only cover an element of the ES.

4.3.2 Monetary Natural Capital Accounts

In this section I outline the methods used for the calculation of each ES and other benefit. Please refer to Hölzinger and Grayson (2019) for more details on the methods, calculations and physical NCAs which are not further outlined within scope of this thesis chapter.

<u>Property value uplift</u>

One of the factors impacting on property value is the local availability of natural greenspace because people have a preference for living in greener areas where they can benefit from its amenity, recreational and health benefits (Mourato et al., 2010). To reveal the implicit NC value contained in property prices in Birmingham, I applied the Hedonic Price Method (HPM) for a benefit transfer. The HPM is used to compare properties with otherwise comparable

[30] For the high estimate of the sensitivity analysis of capitalised values, a lower discount rate of 3.0% (1.0% reduced rate) has been applied in line with Green Book recommendations.

characteristics such as similar number of bedrooms and similar distance to the next work area, only based on the surrounding NC characteristics such as the local availability of open greenspace.

Using the HPM to assess the implicit value of NC 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). Vivid Economics (2017) for example estimated the value of open spaces in Greater London using evidence from an HPM study. Here, I apply the benefit transfer approach to estimate the property value uplift from NC managed by Birmingham City Council using two different primary valuation studies (Gibbons et al., 2014; ONS, 2018b). The outcomes of both assessments were then averaged to inform the central value estimate.

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 NC value in the property value, there is also an implicit NC element in the Council Tax paid by residents. One might hypothesise therefore that, if NC in Birmingham declined, Council Tax income would also decline, at least in the longer term.

In its budget for 2017/18, Birmingham City Council forecasted the Council Tax income to be £308.5 million (Birmingham City Council, 2017a). To estimate the amount of Council Tax attributable to NC managed by the Council, I multiplied the total estimated Council Tax income of £308.5 million by the overall property price uplift due to Council-managed NC which is 9.2% (central estimate). The assumptions underlying this include that there is a linear correlation between property prices and Council Tax income and that NC would not exist if the land was not managed by Birmingham City Council. To my knowledge, this was the first time that Council Tax uplift due to NC has been calculated.

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 provide, I adapted[31] the approach developed by White et al. (2016). A similar approach was also used to develop urban NCAs for the UK for Defra and the ONS (Eftec, 2017; ONS, 2018a).

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 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)

To estimate the monetary value of mental health benefits provided by greenspace managed by Birmingham City Council, I 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.

Air quality regulation

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). Complex vegetation and particularly trees have a positive effect on the regulation of air quality (Nowak et al., 2006; van Oudenhoven et al., 2012).

[31] The adaptation mainly relates to applying an updated value for a QALY in line with HM Treasury Green Book (2018) recommendations.

Jones et al. (2017) developed valuation estimates of air pollution removal at the national scale for the ONS. 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[32] and avoided deaths at the regional level. For Birmingham as a whole, the benefits of air quality regulation by NC was estimated to be in the region of £19.4 million in 2015 (adjusted to 2018 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 NC managed by Birmingham City Council, the area of woodland has been used as a proxy.[33] GIS software was used to quantify the total area of woodland in Birmingham (1,583 ha) as well as the area managed by the Council[34] (1,147 ha). This allowed me to estimate the air quality regulation value attributable to Council-managed NC.

Recreation

The cultural ES 'recreation' usually refers to doing things and interacting with others (Church et al., 2011). NC assets such as parks provide the setting for a wide range of human activities including walking, running, cycling, climbing for informal relaxation (see for example UK NEA, 2011a).

To calculate the recreational value provided by NC assets managed by Birmingham City Council, the Outdoor Recreation Valuation (ORVal) toolkit version 2.0 (Day and Smith, 2018a) was used. 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. Monetary values are based on the travel cost method (Day and Smith, 2018b).

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

[33] In the UK, 80% of all $PM_{2.5}$ removed by vegetation is attributed to woodland and 88% of the monetary value of air pollutant filtration is attributed to $PM_{2.5}$ (ONS, 2018c).

[34] 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.

To estimate the number of visits to greenspace managed by Birmingham City Council rather than greenspace within the geographical area of Birmingham as a whole, I 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.

Global climate regulation

NC 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).

To estimate the carbon stock in woodland managed by Birmingham City Council, I used average carbon stocks[35] provided by Morison et al. (2012). To estimate the carbon stock for other habitats, estimates provided in Alonso et al. (2012) were used.[36] To calculate the monetary value, the estimated total carbon stored in Council-managed NC has been multiplied by the price for non-traded carbon recommended by the Department of Business, Energy & Industrial Strategy (BEIS, 2019). The average central carbon price over our assessment period of 25 years has been applied.

Food production from allotments

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 NCAs. Here, I adopt a similar approach to estimate the food produced in Birmingham City Council-managed allotments, adjusting for occupancy levels in Birmingham. To estimate the monetary value of this food produce, I 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).[37] The same value was also used to inform national urban NCAs (Eftec, 2017).

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[35] This includes soil carbon stocks down to 1 meter.

[36] This includes soil carbon stocks down to 15 cm.

[37] I appreciate that this reference is somewhat out of date but referring to a literature review by Eftec (2017), this is still the best estimate available to date.

Biodiversity (non-use benefits)

Biodiversity underpins all ES as all, at least partially, depend on living organisms and processes (UK NEA, 2011b). Hence, the value of biodiversity is partially implicit in all NC assets assessed within the scope of this investigation. Here, I focus on the non-use values of biodiversity. Non-use values refer to human preferences for protecting and enhancing biodiversity without directly experiencing it such as through wildlife watching (Morling et al., 2010).

To quantify the monetary non-use biodiversity value of woodland in Birmingham, the findings provided by Hanley et al. (2002) were used for a benefit transfer. 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). 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. The assumption underlies that the per-ha values across the UK are representative for per-ha values in Birmingham as well.

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 (European Commission, 2012).

To calculate the value of flood risk regulation services, the findings from Christie et al. (2011)[38] were used for a benefit transfer. A direct correlation between the area of habitat and the provision of flood risk regulating services has been assumed. It should be stressed, however, that flood risk regulation services are very context-specific (Smithers et al., 2016) and the figures shown here are not based on the specific context of Birmingham but a UK average.

4.3.3 Aggregation of Asset Values

A key challenge of NC accounting relates to double counting. The risk is even higher when quantifying such a wide range of services and benefits as in the present study. The ecosystem

[38] In Christie et al. (2011) flood risk regulation has been phrased water regulation.

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 (ONS, 2018a).

Therefore, particular attention has been paid to ONS's Hedonic Pricing Method (HPM) methodology which outlines potential overlaps between property price uplifts on the one hand and ES and other NC benefits on the other (ONS, 2018b). Based on that assessment and the specific quantification methods I used, an indicative value overlap assessment has been conducted summarised in Figure 4.5. Potential value overlaps between service/benefit domains have been outlined in more detail in Hölzinger and Grayson (2019).

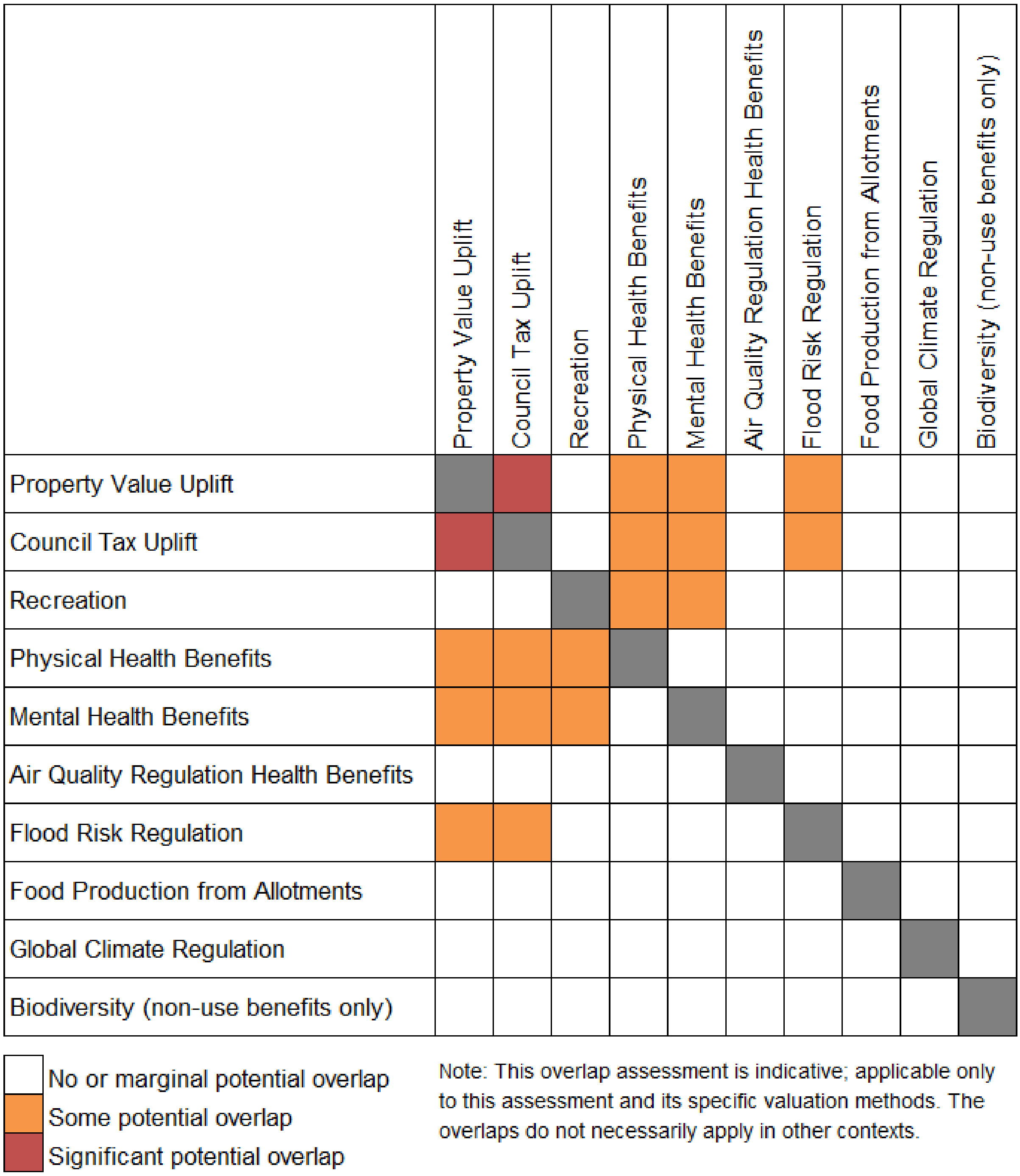

Figure 4.5 Indicative Value Overlap Assessment. The figure indicates the potential overlap between values calculated for assessed services and benefit domains.

Below I outline in Table 4.2 and Table 4.3 which potential overlaps occur between property value uplift, recreation, and other services and benefits. Further corrections to the Council Tax uplift were 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.

Table 4.2 Potential Overlap Correction: Property Value Uplift. The table shows how the property uplift value has been adjusted to mitigate double-counting and to make the value suitable for value aggregation.

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 w ithin 1 mile from home. Other visits are from outside the local area around the visitor's property w hich means overlaps w ith property value uplift are unlikely.
Mental Health	£0.20	33%	-£0.07	£4.74	66%	Some potential overlap is possible. In absence of alternatives, I 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, Iassume 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 w ithin the property value uplift
Note: All values are stated in £ billions; 2018 prices.						

Table 4.3 Potential Overlap Correction: Recreation. The table shows how the recreation value has been adjusted to mitigate double-counting and to make the value suitable for value aggregation.

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 I assume that the overlap is in the magnitude of 33%. Here, I use the recreational value as 'total asset value' because the total physical health benefits are higher than the recreational benefits. Effectively, I am 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, I assume that the overlap is in the magnitude of 33%.
				£1.03	**63%**	
Note: All values are stated in £ billions; 2018 prices.						

4.3.4 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 Fund (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 were capitalised over 25 years, applying a discount rate of 3.5%. The assumption underlies that costs and benefits will remain unchanged over time.

Table 4.4 Conventional Parks Accounts based on Birmingham's Parks Budget for 2018/19. *Source: Based on data provided by Birmingham City Council*

	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.		

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

4.4 Results

The results of the Birmingham NCAs and Health Economic Assessment are summarised in Table 4.5 for stock and capitalised flow values over an assessment period of 25 years. Annual and annualised values are presented in Table 4.6.

The assessment shows that Council-managed parks and greenspaces represent a net NC asset with an indicative value of £11 billion over 25 years. 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.[39]

[39] 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.

Table 4.5 Birmingham Natural Capital Balance Sheet: Stock/Capitalised Values over 25 Years. The table shows the NC stock values and net present values to society, in health benefits, for the Council and for comparison the conventional parks accounts.

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)

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.

Table 4.6 Birmingham Natural Capital Balance Sheet: Annual(ised) flow values. The table shows the annual NC flow values and annualised stock values to society, in health benefits, for the Council and for comparison the conventional parks accounts.

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

The annual accounts (Table 4.6) 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.

4.4.1 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.

Table 4.7 Birmingham Natural Capital Balance Sheet: Sensitivity Analysis of Stock/Capitalised Values. The table shows the stock and capitalised high and low estimates of the sensitivity analysis to society, in health benefits, and for the Council. For conventional accounts no sensitivity analysis was conducted.

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***

Table 4.8 Birmingham Natural Capital Balance Sheet: Sensitivity Analysis of Annual(ised) Values. The table shows the annual and annualised high and low estimates of the sensitivity analysis to society, in health benefits, and for the Council. For conventional accounts no sensitivity analysis was conducted.

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***

4.5 Discussion

In recent years NCAs have been calculated at the national scale (ONS, 2019b) but relatively few regional examples exist (Eftec, 2018; Vivid Economics, 2017). However, much of the strategic planning of green infrastructure is conducted at the regional scale and many parks and greenspaces are managed and funded by local authorities (Birmingham City Council, 2013, 2017a). This is why NCAs are highly relevant at this scale. Local NCAs provide decision-makers and greenspace managers with an improved evidence base by getting closer to the true value of NC and how it supports and enhances human wellbeing. This study adds to the evidence base of regional NCAs in the UK and provides Birmingham City Council with a new evidence base on the value of their NC assets. It builds on provisional NCAs for Birmingham (Hölzinger and Sadler, 2016) which, to my knowledge, were the first city-wide NCAs in the UK. Unique is also the calculation of Council Tax uplift due to NC in the present study as, to my knowledge, this is the first time this has been attempted.

These NCAs shows the magnitude of the impact rather than an exact figure. But already the great British economist John Maynard Keynes said that *"it is better to be roughly right than precisely wrong."*[40] And that was exactly the aim of this assessment – to be roughly right by getting as close to the true NC value as possible rather than being precisely wrong by ignoring and neglecting value domains that are more difficult to quantify. The purpose of the assessment was to reveal the magnitude of NC value rather than a precise value (see also ONS and Defra, 2017).

It needs acknowledging that NC accounting is a developing area of research which is, and probably always will be, imperfect. This is why particular attention needs to be paid to transparently outlining its caveats and limitations. Uncertainties should also be addressed by implementing sensitivity analysis (Defra, 2007) as done in the present study. In fact, the estimates here are still likely to understate the real total NC value. This is because some of the assessed ES 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, local climate regulation 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 NC over time which is not factored in into the calculations.

Given that decision-makers are unlikely to read and understand the full detail of this and other NCAs in their entirety, it is important to guide them with the interpretation of results to mitigate possible misinterpretations and this is particularly so for publications aimed at a practitioner audience (see for example the executive summary in Hölzinger and Grayson, 2019).

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

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

The scientific evidence for valuing NC, however, is developing quickly which improves the availability and quality of valuation studies and therefore the extent to which NC values can be assessed in monetary terms. It thus may be possible to update NCAs more frequently than previously which will clearly benefit Birmingham. A spatially explicit analysis of NCAs will also allow to identify which communities in Birmingham benefit least from NC and where in Birmingham NC interventions may therefore be most beneficial.

Further research is required on the aggregation of value domains as there is a great danger of double counting when aggregating a wide range of service and benefit quantifications as in the present study. In this investigation, I applied a pragmatic approach by estimating the overlaps between value domains and applying proxy weights. However, I acknowledge that this is an experimental approach which needs to be tested and further refined. However, I was cautious and did not add Council Tax uplift to the property value uplift as there are arguments for and against doing so (see Hölzinger and Grayson, 2019 for more details). This is an area to be further explored, too.

With respect to the Birmingham context, it is sensible to expand the assessment scope to all NC assets in Birmingham, including those that are not managed by the Council. Such an assessment would provide a clearer picture of the value of the total NC stock in Birmingham. It would also help other organisations in Birmingham with NC management/stewardship responsibilities to assess the value of NC both, to them and to society. To best facilitate this, such an assessment should include a break-down per stewardship organisation.

It is also sensible to conduct a scenario analysis of how NC values would change in the future under different investment and management regimes. This would provide decision-makers with quantified and evidence-based information on a set of choices for future greenspace management in the city. The Future Parks Accelerator funding recently awarded to the Council may provide a good opportunity window for such analysis.

Last but not least, it is in my view very important to make the issue of NC management and value relevant across a wider range of policy fields as virtually all have interdependencies with NC. This is why this study paid a particular emphasis on the health benefits of Birmingham's NC as already indicated in the title. Public health is consistently high on the political agenda as well as public perception. But the links to NC may be less well known. In my view it is important to take advantage of such ‘policy hooks’ to make more decision-makers aware of how NC contributes to their policy agenda which will hopefully encourage greater cross-sectoral collaboration with respect to NC management.

4.6 Conclusions

This investigation shows just how important it is to account for NC 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 is 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 based on conventional accounts can therefore lead to adverse consequences. Accounting for the value of NC gives us a much better estimate of the value Council-managed parks and greenspaces add to society.

Within this investigation, particular attention has been paid to developing the business case for Birmingham City Council to manage NC sustainably. This is why I included the impact of NC on Council Tax income in my calculations. To my knowledge the first time this was attempted. The Council Tax uplift calculation in this investigation shows that, if investment in Council-managed NC 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 NC 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 NC 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 – the potential beginning of a downturn spiral. That is in addition to significant NC benefits to society that could be lost when reducing investment in parks and greenspaces.

5 Chapter Five: Planning for Sustainable Land-use - The Natural Capital Planning Tool (NCPT)[41]

5.1 Abstract

The main aim of this research project was to devise a reliable and industry acceptable assessment methodology based on ecosystem services (ESs), for major planning applications; that could determine the maximum potential outcomes for natural capital (NC) over a 25-year assessment timescale post-development. With the expressed intention of returning a net positive for NC over this timeline - enhancing human wellbeing and biodiversity value alike. The net result of this research is presented here as the Natural Capital Planning Tool (NCPT) which has been applied for two case studies in Birmingham and Central Bedfordshire.

The NCPT is a site assessment tool developed specifically for the planning context. It allows the indicative but systematic assessment of the likely impact of proposed plans and developments on green infrastructure (GI) and the ESs it provides to people. The NCPT was designed as a fit-for-purpose Excel tool which can be applied with little training by non-specialists and in a comparatively short period of time; balancing the need for translating complex ecosystem science into meaningful metrics and the time- and resource constrains planning practitioners face in everyday practice.

The tool developer believes that the NCPT can help to create more sustainable places for people and wildlife alike, whilst at the same time delivering the housing and infrastructure

[41] This Chapter is based on three previous NCPT publications: (1) Hölzinger, O., Laughlin, P., Grayson, N., 2015. Planning for Sustainable Land-Use: The Natural Capital Planning Tool (NCPT) Project. RICS, London, (2) Hölzinger, O., Sadler, J., Scott, A., Grayson, N., Marsh, A., 2019. NCPT – managing environmental gains and losses. Town and Country Planning May 2019, 166–170, and (3) Hölzinger, O., Sadler, J., Scott, A., 2018. Natural Capital Planning Tool Introduction & User Guide v1.3.3. CEEP, Birmingham. Furthermore, extracts from the following publications may be replicated in this Chapter: (4) Hölzinger, O., 2018. Natural Capital Planning Tool Briefing Note. CEEP, Birmingham, (5) Hölzinger, O. & Grayson, N., 2018. NCPT Case Study Report: Langley Sustainable Urban Extension. CEEP, Birmingham and (6) Hölzinger, O. & Marsh, A. 2018. NCPT Case Study Report: Central Bedfordshire Land Allocation. CEEP, Birmingham. The contents of these publications were partially amended to be suitable for inclusion in this thesis. The contributions co-authors listed above made to this chapter are limited to editorial comments. The exception is the results section and in particular the sections on impact to which the co-authors Grayson, N. and Marsh, A. directly contributed by providing their respective views on the impacts the NCPT application has had. All publications listed above can be accessed from www.NCPTool.com.

the country needs. It also has great potential for operationalising the Governments' ambition for 'environmental net-gains' in the planning system.

5.2 Introduction

Balancing the need for additional housing and the infrastructure that comes with it with the need to create sustainable places that satisfy the needs of people and wildlife for decades to come is a major strategic planning challenge (HM Government, 2011; RTPI, 2015). Planning authorities have to deal with diverse and often competing demands such as affordable housing, biodiversity, climate change and economic growth (Mell, 2014; Scott and Hislop, 2019; Wilker et al., 2016). Planning practitioners are expected to balance and satisfy these demands based on incomplete information and often face a 'document overload' which makes it almost impossible to identify and systematically assess all relevant information related to GI impacts and benefits.

One key component of infrastructure, namely GI, often gets eroded in this process. This is partially due to the cross-cutting character of GI as it both, affects and is affected, by diverse demands from separate sectoral silos leading to potential policy inefficiency and disintegration (Kerslake, 2014; Scott et al., 2013). GI has been championed as a spatial planning tool under the generic heading of nature-based solutions with the potential to integrate these major planning challenges within more holistic social-ecological systems thinking (Forest Research, 2010). But this is only recently being crystallised into a rapidly developing policy arena. Here, I focus on the NC character of GI and the ESs it delivers.

> *"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)

ESs are *"the benefits people obtain from ecosystems"* (Millennium Ecosystem Assessment, 2005, p. V).

Information about the impact of new development on NC and ESs is usually not systematically assessed in the planning context (de Groot et al., 2010). This can also be evidenced by the fact that the term ‘ecosystem services’ is stated exactly once and ‘natural capital’ twice in the latest National Planning Policy Framework with no requirement for systematic assessment (MHCLG, 2018). Also, relevant information on or related to ES is often spread across different planning documents rather than being available in one place.

Traditionally, environmental quality has been assessed in a silo-based approach for discrete areas such as water or air rather than assessing the impact more holistically (Baker et al., 2013). Whilst environmental enhancements are encouraged in English planning policy, there is no statutory requirement to do so:

> *“Planning policies and decisions should contribute to and enhance the natural and local environment…”* (MHCLG, 2018, p. 49)

The ‘should’ indicates that this is more of an aspiration rather than a requirement. This also means that being compliant with planning regulations does not necessarily translate into ‘net environmental gains’ as promoted in the revised National Planning Policy Framework (MHCLG, 2018).

Whilst more and more planning authorities and developers recognise the importance of systematic NC management, they often lack the time, resources and expertise to do so. Ecosystem science is very complex and the systematic assessment of ESs even provides a challenge for specialists (UK NEA, 2011a). Hence, it cannot be expected from planning practitioners to assess NC impact without assistance. This is why I developed the NCPT – to give planners and developers a tool to hand to systematically assess and manage the impact of land-use changes on ESs.

The development of the NCPT was initially funded by the Royal Institution of Chartered Surveyors (RICS) Research Trust (project reference number: 477). The injection of the NCPT into green-blue infrastructure management was later funded by the Natural Environment Research Council (NERC; NE/N017587/1).

5.2.1 Drivers of Land-use Changes and its Impact on Natural Capital and Ecosystem Services

In the United Kingdom and worldwide, the population is growing and urbanisation is increasing. The world population is projected to grow by almost 800 million by 2030 and nearly 2 billion by 2050 (UN, 2019a). Whilst more than half of the world's population (55%) already live in cities, virtually the entire projected future population growth is expected to take place in urban areas (UN, 2019b). In the UK, the population is projected to grow by 6 million (9%) over the next 25 years to 72.4 million in 2043 (ONS, 2019c).

In Birmingham alone, the population is expected to grow by 152,700 (13.5%) from 1.13 million in 2016 to 1.28 million in 2036 (Birmingham City Council, 2018a). This necessitates the development of additional housing, services and associated infrastructure – all constrained by the city boundary. This scale of development will be reflected across many local authorities over the same timescale.

Notwithstanding the many opportunities and advantages associated with such growth, developments can also have negative impacts on the environment, the economy and people's wellbeing more generally. The UK National Ecosystem Assessment (2011) has found that land-use changes, such as due to development, can impact on the extent and ability of NC to provide ESs such as space for recreation, the mitigation of flooding events and air quality regulation; all of them including their associated health and wellbeing benefits. many ecosystems in UK cities, but also on the countryside, are already in degraded and/or declining status (UK NEA, 2011b). This means that the provision of ESs including their wider benefits to people's wellbeing cannot be taken for granted and needs to be actively managed and protected. The Government's 25 Year Environment Plan (2018) highlights the need for action:

> *"Green infrastructure brings wider benefits, including sequestering carbon, absorbing noise, cleansing pollutants, absorbing surface water and reducing high temperatures. The number and condition of green spaces has declined and current investment is confined to specific projects. We risk losing more good quality green spaces. As we build more homes, preserving and creating green spaces in towns is more important than ever. Local authorities and developers need to take account*

of all the benefits when deciding how much land to allocate as green space." (HM Government, 2018, p. 79).

One of the main drivers of NC and ESs degradation is land-use change caused by development (Bastian et al., 2012; Dallimer et al., 2011; IPBES, 2018; United Nations, 2013). Because NC is not often traded on markets, it lacks a market price which can lead to its undervaluation and presents an incentive for its over-exploitation (NCC, 2015). The projected population growth and urbanisation is likely to increase the pressure on NC. The expected population growth also means that the demand for ESs such as recreational opportunities increases (Graham and Eigenbrod, 2019). Hence, in a 'business-as-usual' scenario it can be assumed that the provision of ESs will decline whilst the demand for ESs increases at the same time. This is an unsustainable development path which is likely to endanger the wellbeing of future generations if no action is taken.

5.2.2 Demand and Barriers for Ecosystem Services Assessment Tools

The value of ESs has been assessed at the global (Millennium Ecosystem Assessment, 2005), national (UK NEA, 2011b) and city scale (Hölzinger et al., 2013b; Hölzinger and Grayson, 2019). However, this evidence only slowly emerges in planning policy. In 2011, the Government acknowledges in its Natural Environment White Paper that the system is not yet fit for purpose to deliver sustainable land-use:

> *"The Government expects the planning system to deliver the homes, business, infrastructure and thriving local places that the country needs, while protecting and enhancing the natural and historic environment. Planning has a key role in securing a sustainable future. However, the current system […] is failing to achieve the kind of integrated and informed decision-making that is needed to support sustainable land-use."* (HM Government, 2011, p. 21).

Subsequently in 2012, the crucial importance to protect and enhance ESs has been addressed in the (now revised) Government's National Planning Policy Framework:

> *"The planning system should contribute to and enhance the natural and local environment by […] recognising the wider benefits of ecosystem services"* (DCLG, 2012, p. 25).

But so far, the Government has not equipped developers and planning authorities with the necessary practical tools to assess and manage these benefits which hinders them from implementing such strategic guidance.

Implementing the value of NC and ESs into spatial planning and land-use management is not a new idea and has certainly attracted research interest (see for example de Groot et al., 2010). One can see from the literature that scientists call for the implementation of ESs and NC values into spatial planning and land-use management (Bastian et al., 2012; Hermann, 2011; Koschke et al., 2012; Raymond et al., 2009; Scott et al., 2018). The need for software tools has also been highlighted (Egoh et al., 2007). However, the uptake of the ESs concept in spatial planning is still poor (see for example Mascarenhas et al., 2014).

The systematic assessment of ESs and NC within scope of a development project can be very challenging and faces a range of barriers. It is arguable that one main reason for this lack of implementation is that relevant evidence, for example from national assessments of ESs (UK NEA, 2011b), is hard to assimilate and to take up at the local and site scale where most planning decisions take place. Relevant evidence cannot easily be downscaled or adjusted to be useful for the specific local planning context (Hölzinger et al. 2014).

Another barrier is that ESs thinking and its dedicated terminology can be very complex and developers and planning authorities are often not familiar with the concept and related methodical approaches. Also, developers and their agents do not always have ESs expertise available in-house. The same applies for many planning authorities. In 2011 only about 40 per cent of English local authorities had an in-house ecologist and in 2007 planning officers only received ecological advice for just over 50 per cent of their planning cases[42] (Parliamentary Office of Science & Technology, 2013). The Association of Local Government Ecologists (ALGE) estimates that, to date, about two-thirds of local authorities do not have an in-house ecologist or ecology team.[43] It should also be mentioned that such ecologists are often specialised on biodiversity issues rather than the wider concept of ESs. This limits their ability to assess and judge the impact of proposed development projects on ESs and to compare related values

[42] Figures are based on a sample.

[43] Email communication with Elizabeth Milne from ALGE on 5th November 2019.

and their inherent impacts on human wellbeing with other benefits such as the creation of new housing or jobs.

Even if developers and planning authorities are equipped with the necessary expertise, they often lack the resources and time to undertake a holistic in-depth analysis of ESs impacts. Because of the complexity of ecosystem science and the wide range of potentially relevant datasets and resources to consider, it is often difficult (1) to gather and analyse relevant data (if available); (2) to translate such data into useful indicators; and (3) to meaningfully aggregate and interpret the findings. Even if site-specific assessments are available elsewhere it can be very challenging to replicate such studies for the policy site (Scolozzi et al., 2012).

There are tools available allowing to assess the impact of land-use changes on NC and ESs values including the Natural Capital Asset Check which was developed as part of the UK National Ecosystem Assessment Follow-On (UK NEAFO) research project funded by the UK government (Dickie et al., 2014). Further tools that could be used for such an assessment include Social Cost-Benefit Analysis and Multi-Criteria Decision Analysis (see Scott et al., 2014 for an overview). However, such detailed assessments are resource intensive and therefore difficult to fund at the site scale – for example for a development site or a master plan. The application of such tools is also very demanding in terms of the expertise required and time commitment.

At the moment the planning system in England and in much (if not all) of the rest of the world is not systematically accounting for the impact of development and inherent land-use changes on NC and ESs, although relevant tools are slowly emerging (Grêt-Regamey et al., 2017; Smith et al., 2018). A fit-for-purpose tool that generates proxy values for such assessments not only provides a valuable opportunity to fill this gap; but could also become an acceptable and workable industry standard.

Assessing development impacts on NC is an important step towards integrated ESs and NC management and decision-making because ‘what gets measured gets managed’. Without assessing the impact of planning and development on NC and ESs, planning authorities and governmental institutions will not be able to set the right incentives to protect and enhance these valuable assets and therefore ensure sustainable land-use decisions.

5.3 Methodology

The NCPT enables the assessment of the impact of development and land-use changes across 10 different ESs and is based on a Multi-Criteria Decision Analysis (MCDA) framework (see also Hölzinger et al., 2014b; Sunderland and Hölzinger, 2013). For each assessed ES, a set of feasible indicators was identified. Because of the gaps in the published scientific literature, an expert and stakeholder knowledge-based approach has been taken to establish values to features; for example, for the level of ESs provided by different land-use classes.

The development of the NCPT builds upon a former research project which was funded by the Government's Department for Environment, Food and Rural Affairs (Defra) with additional support provided by industrial partners. A so-called Natural Capital City Tool (NCCT) was developed as the main outcome of that project in 2014. The purpose of the NCCT was to introduce a structured framework and mechanism for planners and developers to assess the impact of development on the provision of ESs. The NCPT advances the NCCT by introducing a simplified and automated mechanism with pre-defined scores for ES impacts. This significantly reduces the time and expertise required by the tool user and therefore also allows planning practitioners to use the tool without expert advice.

5.3.1 Project Scope

Within recent decades, NC and ESs research has become an important concept (Millennium Ecosystem Assessment, 2005; UK NEA, 2011b). This is an interdisciplinary area of research and the number of relevant publications, indicators and methods is vast and further evidence is added almost on a daily basis. It was therefore clear from the beginning that within scope of this project it would not be possible to identify and incorporate all relevant evidence to create a 'world-tool' for all possible circumstances. Therefore, I had to restrict the scope of the research to a workable range of ESs and indicators to be assessed by the NCPT.

Acknowledging the high complexity of ecosystem science and the many gaps in the scientific evidence, I did not aim to develop a perfect tool that generates 100% accurate outcomes; but to give the target audience, planners and developers, something to hand that can be easily applied in practice and that generates proxy values indicating the direction and magnitude of development impacts on NC values. It was intended to develop a pragmatic and user-friendly ‘rough and ready’ tool that generates better outcomes compared to the status quo where many NC impacts remain unaccounted for.

At the first project steering group meeting held on 5th September 2014 in Birmingham, a list of 10 ESs to be assessed by the NCPT has been confirmed which is outlined in Table 5.1.[44] The selection of ESs to be assessed by the NCPT was based on data and indicator availability considerations as well as stakeholder views on their significance in the planning context which I explored through a range of email and face to face communications prior to the first steering group meeting.

Table 5.1 Assessed Ecosystem Services. The table shows all ESs assessed including a short description of each service.

Ecosystem service	Narrative
1. Harvested products	Impact on the production of food, timber and other products harvested from ecosystems
2. Biodiversity	Impact on habitat composition and connectivity
3. Aesthetic values	Impact on the visual amenity of a site
4. Recreation	Impact on the availability and accessibility of public greenspace
5. Water quality regulation	Impact on water quality improving vegetation
6. Flood risk regulation	impact of vegetation on water storage capacities and water run-off
7. Air quality regulation	Impact on vegetation contributing to air quality
8. Local climate regulation	Impact on cooling vegetation reducing the Urban Heat Island Effect (UHIE) – climate change adaptation
9. Global climate regulation	Effect on carbon stored in soil & vegetation – climate change mitigation
10. Soil contamination[45]	Impact on risks to human health and groundwater

[44] The steering group had 13 members. Steering group members who could not attend the meeting in person were given the opportunity to comment via email and consent has been reached by all members. For a full list of steering group members see Appendix 5.1.
[45] In a strict definition ‘soil contamination’ may not be labelled as ecosystem service but for consistency reasons and to improve the readability of this Chapter, ‘soil contamination’ is treated as ecosystem service.

5.3.2 Stakeholder Involvement

Stakeholders have been involved throughout the duration of the project. A project steering group was established at the very start. The main purpose of the steering group was to oversee and review the project progress and to endorse the outcomes and research findings. Members of the steering group were recruited through the existing networks of the core project team and were built upon the group that already steered the former NCCT project; a process overseen by the UK Business Council for Sustainable Development.

The steering group comprised 13 members during the initial tool development phase (2014-2015) and expanded to 47 members in the testing and injection phase (2016-2018), indicating the great interest in the project. The steering group included business and local authority representation as potential future users of the tool, representatives from relevant governmental bodies such as the Environment Agency and Natural England, as well as representation from academia and third sector organisations (Appendix 5.1). Main aim of this steering group was to agree on the methodical approach taken for this project, to ensure the quality and validity of the NCPT and other project outcomes, to review (interim) findings, and to help test the tool on various case study sites. The steering group met in Birmingham 3 times throughout the initial tool development phase duration on 5th September 2014, 11th December 2014 and 16th April 2015 as well as 3 times during the testing and injection stage on 29th April 2016, 26th June 2017 and 1st February 2018.

In addition to the steering group, specialists' task groups were established. The project team has, with support of the steering group, invited members for 10 different task groups, each one of them to assess the impact of planning and development on one of the selected 10 ES. Task groups were composed of experts from academia and relevant governmental institutions as well as practitioners; for example, from third sector organisations, local authorities and businesses. Altogether the project team was able to recruit 45 task group members during the tool development phase (see Appendix 5.2).

Table 5.2 Task Group Members. The table shows the number of task group members participating in scoring exercise for each assessed ES.

Task Group	Members
1. Harvested products	6
2. Biodiversity	12
3. Aesthetic values	7
4. Recreation	7
5. Water quality regulation	8
6. Flood risk regulation	6
7. Air quality regulation	4
8. Local climate regulation	8
9. Global climate regulation	8
10. Soil contamination	6

The main tasks for the task groups were (1) to select a set of feasible indicators to inform the assessment of each ES; (2) to identify data and information sources to inform the indicators; and (3) to participate in a scoring exercise to define ES related scores to features; for example different land-use options as outlined further below.

5.3.3 NCPT Land-use Classification Framework

As the NCPT focuses on the assessment of land-use changes, it is not surprising that many indicators relate to land-use types. Therefore, it was very important to work with a comprehensive land-use classification framework. Unfortunately, a fit-for-purpose framework suitable for the NCPT did not exist and had to be developed as part of the project.

With the support from selected steering group members, I established a comprehensive NCPT land-use classification framework. The framework is based on the Joint Nature Conservation Committee (JNCC) Phase 1 habitat survey and classification framework (JNCC, 2010). The JNCC framework is used as a standard method when surveying and mapping habitats in the UK. This framework has been combined with the list of UK Biodiversity Action Plan (BAP) Priority Habitats (BRIG, 2007) to give more detail to the framework; especially in respect to biodiversity values. Furthermore, additional land-use categories relevant in a planning context such as 'buildings covered with green roof' have been added to the framework after stakeholder consultation. Some original JNCC categories have also been omitted when overlaps occur and to reduce the overall complexity of the framework. See Appendix 5.3 for the full NCPT land-use classification framework.

The NCPT accepts land-use information at different levels of detail. The tool user can simply select ‘Woodland and scrub’ if they lack information on the type of woodland (or scrubland). However, users are prompted to always enter the most precise level of land-use information available as this enhances the accuracy of the tool outcomes. This is to acknowledge that detailed habitat information is not always available and it was important that the NCPT can also be applied at an early planning stage where only broad habitat information may be provided.

Table 5.3 NCPT Land-use Classification Framework (Extract). The table shows an extract of the land-use framework developed for the NCPT. Users are able to select broad habitats (A) for high level assessments but are prompted to select more detailed habitat categories (e.g. A1.1.1.a) when relevant information is available.

A	**Woodland and scrub**
A.1	Woodland
A.1.a	Lowland beech and yew woodland (UK BAP Priority Habitat)
A.1.b	Wet woodland (UK BAP Priority Habitat)
A.1.1	Broadleaved woodland
A.1.1.1	Broadleaved woodland - semi-natural
A.1.1.1.a	Broadleaved ancient semi-natural woodland (ASNW)
A.1.1.1.b	Upland birchwoods (UK BAP Priority Habitat)
A.1.1.1.c	Other broadleaved woodland - semi-natural
A.1.1.2	Broadleaved woodland - plantation
…	

5.3.4 Assessment Framework & Scoring Exercise

For the development of the NCPT, a Multi-Criteria Decision Analysis (MCDA) framework has been chosen. MCDA is a structured approach to integrate and evaluate multiple (and often heterogeneous) dimensions and criteria of a decision (Scott et al., 2014). In MCDA, it is common to ascertain scores or weights to different features or impacts of a decision. These scores or weights are usually arrived at by an individual assessor or by a group of assessors (see also Hölzinger et al., 2014b).

Because the target audience for the NCPT - developers and planners - often do not usually have the necessary level of expertise to assess the impact of land-use changes on ESs, this task has been undertaken by the task groups. Figure 5.1 shows the assessment framework for developing the NCPT. For each assessed ES, and therefore each task group, the process followed a similar process with 5 subsequent steps which took place between October 2014 and March 2015.

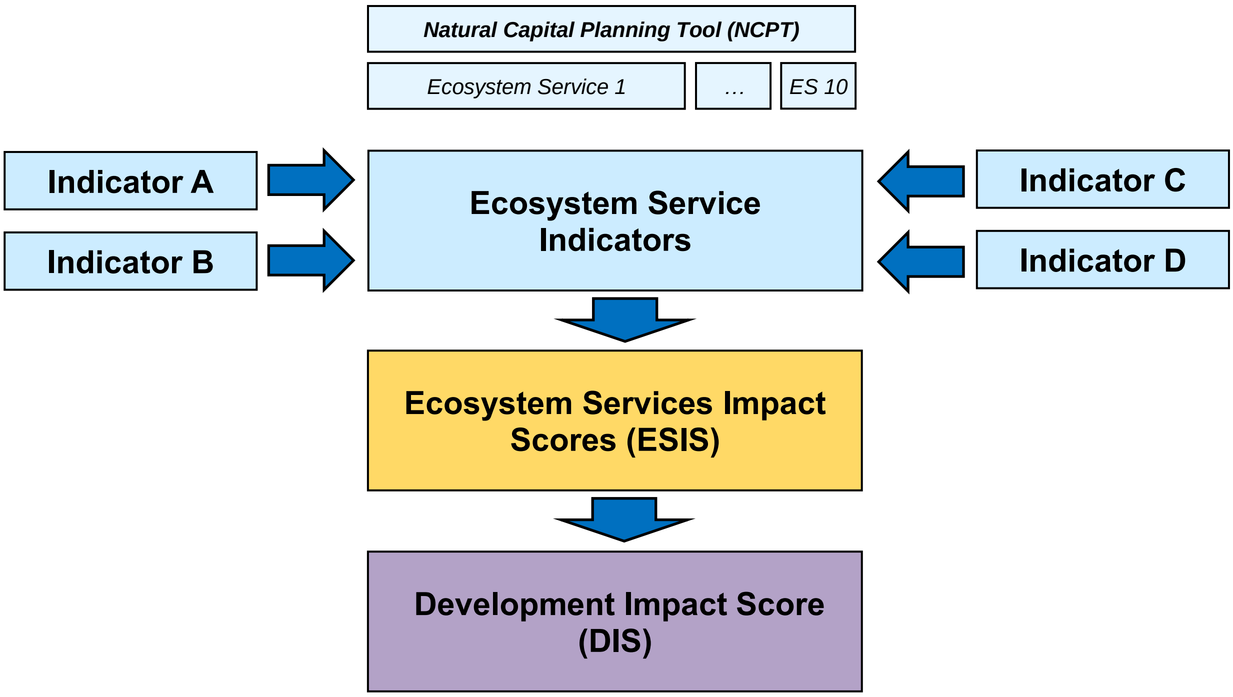

Figure 5.1 NCPT Assessment Framework. The figure shows how for each assessed ES, ES indicators are translated into an ES Impact Score (ESIS) and finally aggregated to a Development Impact Score (DIS).

<u>Step 1: Indicator identification</u>

For each assessed ES, a preliminary literature review was undertaken to identify potential indicators to assess the impact of development and land-use changes. Because ESs are usually not directly informed by readily available indicators and assessment methods, I classified indicators into Input Level Indicators (ILIs) and Assessment Level Indicators (ALIs).

ILIs are those indicators which are readily available to the tool user. They include for example land-use changes, soil type or socio-economic data such as population density. ILIs needed to be 'translated' into ALIs which directly indicate the impact on ESs. When assessing for example flood risk regulation, an ILI would be the land-use and an ALI would be the water storage capacity/water run-off of vegetation associated with each land-use.

Because it was of crucial importance that the NCPT can be applied using existing and readily available datasets, each potential ILI has been checked with a representative from Birmingham City Council planning team and ruled out for the tool if not readily available as part of the planning process in England or from other accessible sources. I aimed to select indicators that are available for most plans and developments.

Step 2: Indicator selection

Here, the task groups selected a set of feasible indicators to assess each ES. As part of an initial literature and data review, almost 60 potential indicators were identified which could potentially inform the NCPT. A short description on why the indicator has been selected, how and where relevant information can be assessed, which assumptions apply, and if the indicator reflects the supply of or demand for ESs has been shared with each task group via email. To limit the complexity of the tool but also the input requirements and time commitment of the tool users - a maximum of 4 indicators per ES were selected by the task group. The selection was based on how well the indicators are suitable for informing ES impact, but also data availability.

Step 3: Indicator confirmation

The pre-selected list of indicators was shared via email with each task group together with a short outline where a method for translating the ILIs into the ALIs was proposed. The task group members were asked to review and comment on selected indicators and proposed methods, with the aim to seek agreement across all task group members. Task group members were also asked to flag up additional evidence that could inform the indicators. How selected ILIs inform ALIs and finally ESs is indicated by the arrows in Figure 5.2.

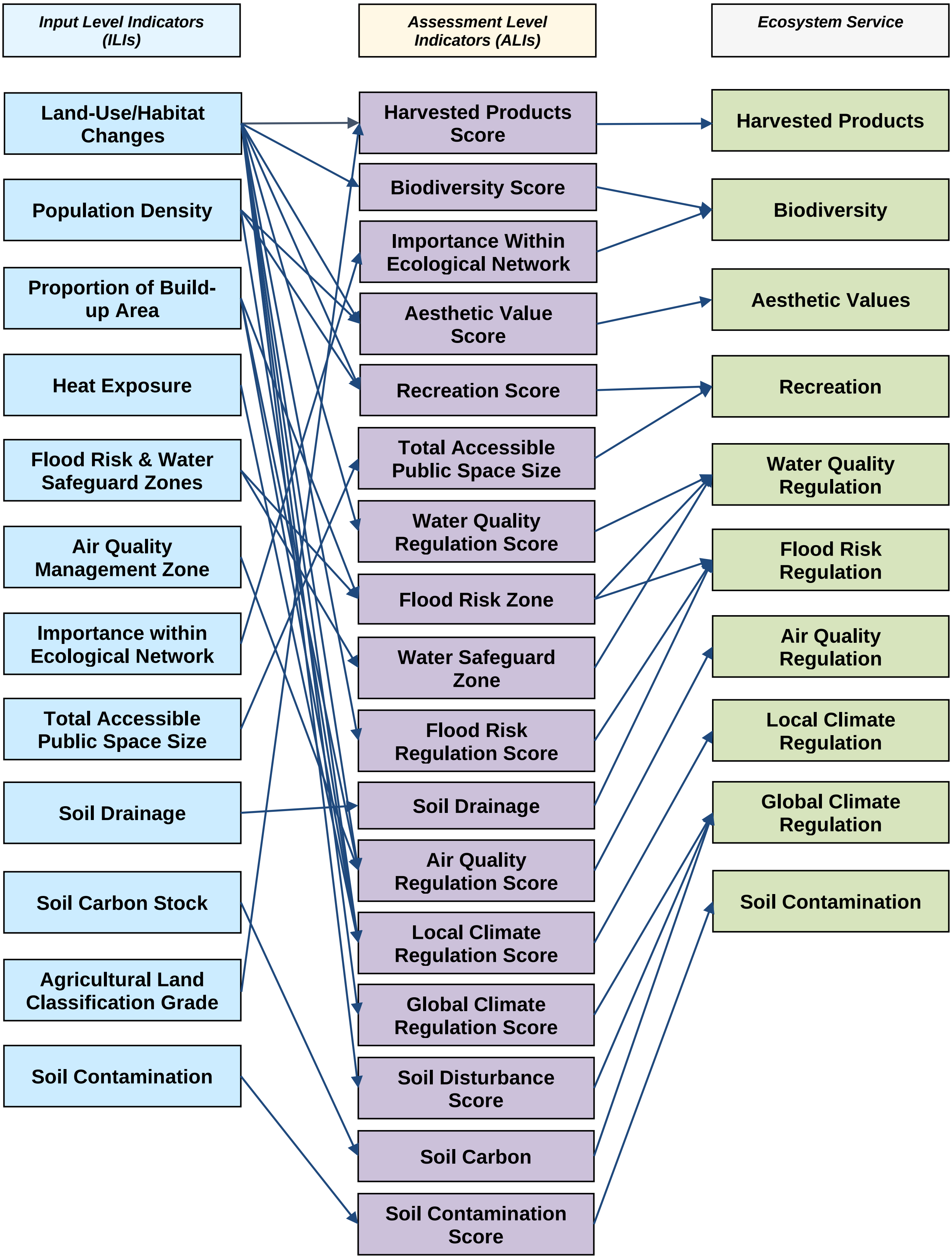

Figure 5.2 Relationship between Indicator Level Indicators, Assessment Level Indicators, and Ecosystem Services. The figure shows, indicated by the arrows, which ILIs inform ALIs and ultimately ESs.

Step 4: Scoring exercise

Because the published scientific evidence to assess ESs is imperfect and reveals many gaps, the translation from ILIs into ALIs was mainly based on expert judgment. In most cases task group members were presented with ILI features (e.g. the NCPT land-use classification framework) and were then asked to establish indicative ALI scores (e.g. the indicative biodiversity values of each land-use type). For this exercise, an excel spreadsheet was circulated via email explaining the purpose and rules of the scoring exercise. Typically, the excel sheet included the NCPT land-use classification list and task group members were asked to select scores from a drop-down menu. The scores typically varied between 0 to 3 and 0 to 5. The range for each land-use score was defined by the task group depending on the level of detail they felt was appropriate to assess each ES.

Usually, task group members were asked to select an average, a minimum and a maximum score for each land-use type. The average score is the proposed score allocated to the ESs value of a specific land-use. The minimum and maximum scores define thresholds within which the tool user can adjust the score to account for circumstances not factored in into the model. A specific land-use type, for example, may have an average biodiversity score of 3 - but if that habitat is in particularly good management and of very high quality - then the tool user has the opportunity to adjust the score to 4. To acknowledge the level of ES provision with respect to the maturity level of a habitat the scoring exercise has been split into 'existing habitats' and 'new habitats'. The scores for the latter are given for a 25-year timescale after the habitat has been created.

Step 5: Scoring confirmation

After the completed excel sheets were returned the scores of all task group members were aggregated. The aggregated scoring results were shared with the task group again to allow a review and to confirm or challenge the outcomes.

Task group members were able to change scores if they could justify the change. If that was the case, the proposed changes including justification were again shared with the whole task group to be confirmed. All task group members had a veto-right so if a task group member did not agree with a changed score then the original aggregated score was adopted. The result was a final set of scored indicators for each of the 10 assessed ESs which have then been implemented into the NCPT model. The scored indicators inform the calculation of an Ecosystem Service Impact Score (ESIS), automatically calculated based on the indicators (ALIs) entered by the tool users. The ESIS is one of the main tool outcomes and shows the impact of the proposed development on each assessed ESs.

To arrive at a single Development Impact Score (DIS) all ESISs for each ES were aggregated. The steering group decided that an equal weight should be applied. But the NCPT can also be modified by applying specific weights to each ES. The DIS is the main outcome of the NCPT and indicates the overall impact of the proposed development on all assessed ESs together. The NCPT Excel spreadsheet was published on a dedicated NCPT website in March 2018.[46] The tool is accompanied by further info material, a guidance document and case study reports (Hölzinger, 2018; Hölzinger et al., 2018).

Essentially, the NCPT automatically calculates an impact score for 10 ESs, indicating both, the direction and magnitude of the impact of a (proposed) plan or development (Figure 5.3). The NCPT indicates, through a simple score, if the change from the existing to the new land-uses provides a net-gain for each assessed service. Furthermore, the NCPT indicates the minimum/maximum possible scores the site is capable of providing for each service.

[46] www.NCPTool.com.

Development Impact Score Average Per-Hectare			
Ecosystem Services Impact Scores	Max Possible	Impact Score	Min Possible
1. Harvested Products	+0.13	-3.04	-3.67
2. Biodiversity	+4.44	+1.24	-0.56
3. Aesthetic Values	+2.09	+0.58	-1.91
4. Recreation	+4.00	+0.78	-0.00
5. Water Quality Regulation	+1.30	+0.37	-1.00
6. Flood Risk Regulation	+0.95	+0.20	-0.05
7. Air Quality Regulation	+0.61	-0.08	-0.30
8. Local Climate Regulation	+2.43	+0.62	-1.19
9. Global Climate Regulation	+4.22	-0.15	-0.78
10. Soil Contamination		+0.00	
Development Impact Score	+20.15	+0.51	-9.46

Figure 5.3 Example of a NCPT results table. The figure shows the impact score for each ES in the main column. The impact is also indicated by the colour code. These are aggregated to the DIS in the bottom row. The maximum/minimum scores the site is capable of providing are indicated to the left and right of the main column, respectively.

To summarise, impact scores are based on a set of habitat scores (e.g. the air quality regulation potential of a certain land-use) as well as a range of multipliers taking into account the local context (e.g. is air quality an issue in the location) and demand (how many people benefit). Impacts are indicated over a timescale of 25 years post-development. How the NCPT works from a user-perspective is outlined in Figure 5.4.

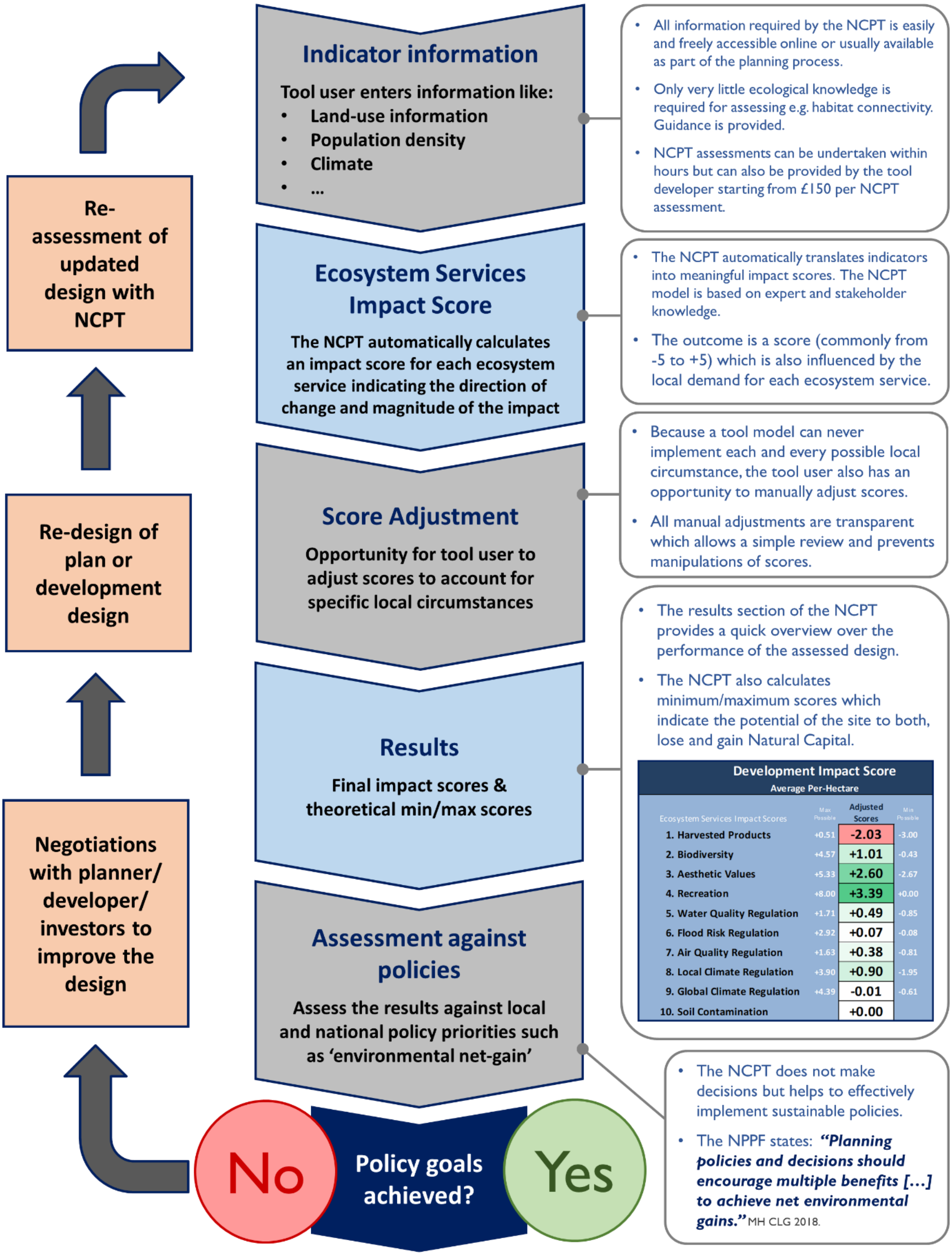

Figure 5.4 How the NCPT works in practical steps. The figure shows and explains the process of applying the NCPT. An assessment starts with the user entering indicator information which informs ES impacts scores calculated by the NCPT. After an opportunity for manual score adjustments, these scores then inform the results which should be assessed against policy goals.

5.4 Results: Case Studies

The NCPT has been tested in different contexts and at different stages of live projects. Initially, it was planned to test the NCPT at 7 case study sites. However, during the development phase the NCPT attracted considerable interest from other organisations with 11 additional partners offering to test the NCPT. Due to timing issues and other factors not all case studies could be completed. However, all case study partners provided valuable feedback which helped to amend and 'ground-truth' the NCPT before it was released in 2018.

The NCPT was applied to at least 20 development sites, both, during the testing phase and after its release. However, it is entirely possible that the NCPT was used more often without my knowledge as it is in the public domain. Here, I highlight two case studies from Birmingham and Central Bedfordshire.[47]

5.4.1 Birmingham Case Study: Langley Urban Extension

Case study site and context

In August 2016, the NCPT was tested on a proposed housing development in Langley in the North-East of Birmingham, in the Sutton Coldfield constituency. To accommodate Birmingham's growing population, 273 ha of Green Belt, dominated by agricultural land with very limited access, was released for the development to create a new city district including 5,000-6,000 new homes, all associated infrastructure, new centres, schools, cultural facilities; and at least 10 ha of new accessible urban greenspace; termed a Sustainable Urban Extension.

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[47] The author would like to thank Nick Grayson, Climate Change and Sustainability Manager at Birmingham City Council and Andrew Marsh, Principal Planning Officer at Central Bedfordshire Council for their valuable feedback informing this Section. Further information on these and other case studies is accessible at NCPTool.com/case-studies/

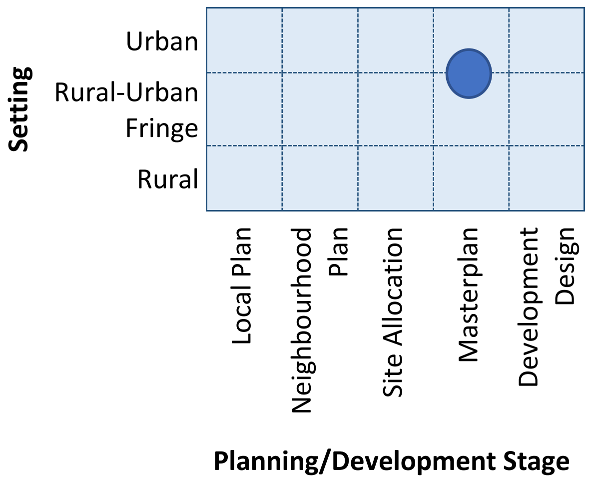

Figure 5.5 Birmingham Case Study Context. The figure shows where the Birmingham case study is contextualised across land-use settings and stages of the planning and development process.

The release of the Green Belt site proved to be a very contentious decision as part of the consultation of the City's Development Plan. The Planning Inspectors were persuaded by the evidence; but it led to a delay of the adoption of the Development Plan. As through this, it was called in by the Secretary of State. Finally, it was accepted based on the decision to develop a Sustainable Urban Extension (SUE) that would not be 'business as usual' in terms of a standard housing development but would deliver an *"exemplar of sustainable development… designed to the highest possible standards… and achieve the highest standards of sustainability"* (Birmingham City Council, 2017b, p. 48) for the City.

Why and how the NCPT was used

The Langley SUE was chosen as case study because of its sensitive and contentious nature. The NCPT was applied to assess as to whether or not former agricultural land could be developed and still return a net gain for NC. Using the NCPT was meant to set the bar for subsequent development in the city.

Right from the start the public pressure and expectation was to see a visually green scheme. The original Masterplan certainly delivered on that aim. 10 years ago, it would have been highly likely that this would have met with approval. The interesting difference that the NCPT brought was to fully examine the functionality of GI. The aim was not to create more GI; but it seeks to create GI that can demonstrate that it works harder - delivering multiple benefits from the same land parcel.

Findings

The NCPT outcomes for the initial outline Masterplan in 2016 indicated losses to several ESs with the most significant losses indicated for harvested products and global climate regulation (Figure 5.6). These losses are due to loosing agricultural outputs, as one would expect when developing on arable land, and due to the replacement of vegetation and disturbance of soils which act as a carbon sink. These two impacts also drive the negative DIS. More marginal negative impacts were also indicated for water quality and flood risk regulation, mainly due to the introduction of impermeable (paved) areas. The losses are opposed by rather marginal gains for biodiversity, aesthetic values and recreation.

Development Impact Score
Average Per-Hectare

Ecosystem Service	Adjusted Scores
1. Harvested Products	-5.4
2. Biodiversity	+0.1
3. Aesthetic Values	+0.6
4. Recreation	+0.2
5. Water Quality Regulation	-0.2
6. Flood Risk Regulation	-0.1
7. Air Quality Regulation	+0.0
8. Local Climate Regulation	+0.0
9. Global Climate Regulation	-1.7
10. Soil Contamination	+0.0
Development Impact Score	-6.5

Figure 5.6 Initial NCPT findings for the Birmingham Sustainable Urban Extension. The figure shows the results of the initial NCPT assessment for each assessed ES and aggregated in the DIS.

Impact of the NCPT assessment

The mere process of assessing this scheme with the NCPT totally shifted both, the local planners and the applicants view of the GI potential for the site. The NCPT findings directly influenced the revision of the first Masterplan.

Subsequently, Birmingham City Council also engaged a visiting Biophilic Cities Planning Masters Fellow from the University of Virginia in late 2016 to test different design options whilst keeping the housing target in place. By adjusting housing densities, accessibility, as well as proximity and connectivity of GI features to the surrounding landscape, it proved possible to achieve the maximum housing number and return a marginal net gain for NC. This adjusted design was not implemented but it provided a proof of concept.

Traditional, landscape planning and development has been driven by aesthetics and recreation, and some recognition of biodiversity. By applying the NCPT, the Council was able to demonstrate the net worth of multiple ESs being delivered back by the same piece of land. This is what is meant by ‘working harder’; addressing more human needs through multifunctional GI being of greater net benefit.

The negative views on the plan expressed by both local politicians and citizens have also been somewhat mitigated by the application of the NCPT - to be able to demonstrate that the landscape left after development has the potential to be delivering more ESs than the original Green Belt - they had felt was sacrosanct.

The influence that this NCPT test has had on the approach can be seen in the draft Supplementary Planning Document (SPD) for the site (Birmingham City Council, 2018b). The original visually green-looking scheme actually failed to demonstrate a net gain across the 10 ESs. The draft SPD now outlines multiple centres inter-linked and permeated by GI in recognition of the learning from the NCPT exercise. In addition, the NCPT helped to appraise the cross-boundary connections - which again are now born out in the draft SPD.

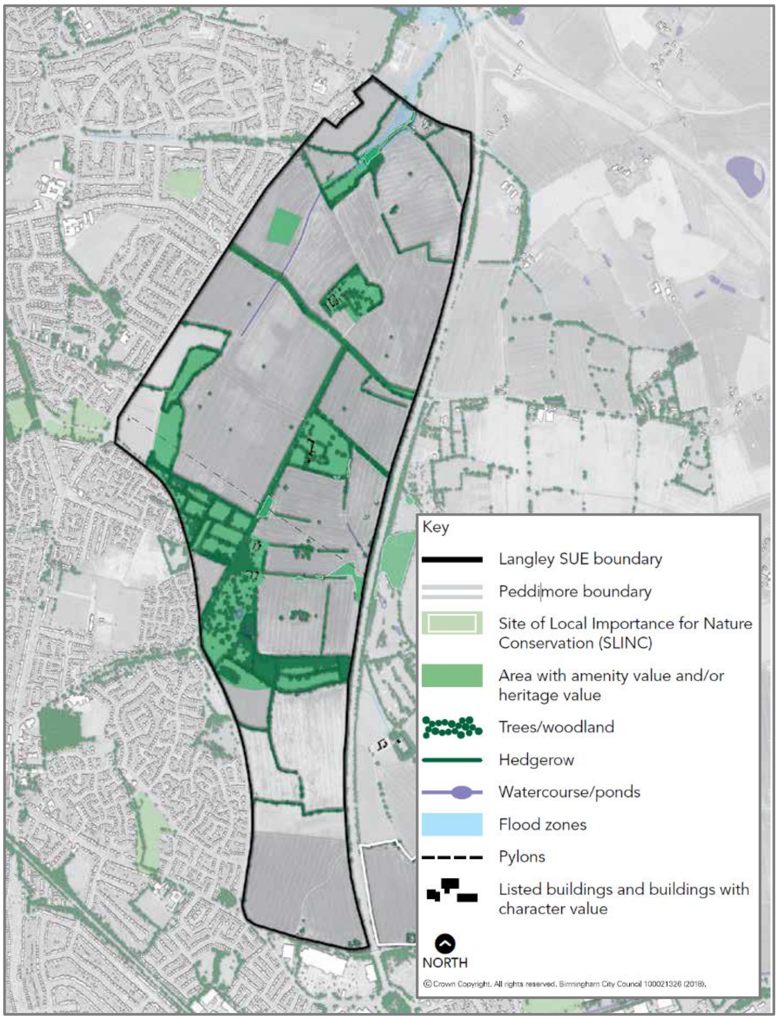

Figure 5.7 Green Infrastructure and Assets of Revised Birmingham Sustainable Urban Extension Plan. *Source: Birmingham City Council (2018) p. 27.*

From a broader city perspective, the learning from this case study can be seen spilling into other major developments by better promoting the integrated benefits of GI - addressing multiple agendas - so not to be drawn up in isolation from the desired outcomes of the overall vision of any scheme.

Birmingham City Council is planning to use the NCPT for future major developments in the city. This could be extended to smaller developments as well if additional funding becomes available. Nick Grayson, Climate Change and Sustainability Manager at Birmingham City Council, gave the following feedback:

> *"With the advent of the 25 Year Environment Plan, its commitment to net gain and the NPPF review (2018) - there is the real possibility of the NCPT providing that all*

important bridging device between national planning policy and the Government's environmental restoration ambitions - at the site scale."

5.4.2 Central Bedfordshire Case Study: Site Allocation

<u>Case study sites and context</u>

Between January and May 2017, the NCPT was used to assess eight potential growth locations in Central Bedfordshire - predominantly housing developments of between 500 and 7,000 units on agriculturally dominated greenfield sites close to transport corridors.

Central Bedfordshire, located between Milton Keynes and Luton, is facing enormous development pressure. The Council's population is expected to increase from 271,500 in 2015 to 325,100 in 2035 (Central Bedfordshire Council, 2017). The Council is planning for another 18,300 homes by 2035. This is in addition to 23,500 new homes that have either already been completed since 2015, allocated, or have already planning permission (Central Bedfordshire Council, 2018).

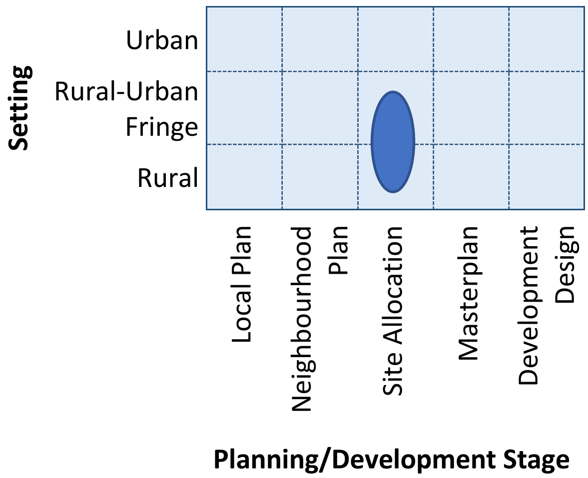

Figure 5.8 Central Bedfordshire Case Study Context. The figure shows where the Central Bedfordshire case study is contextualised across land-use settings and stages of the planning and development process.

<u>Why and how the NCPT was used</u>

Central Bedfordshire Council wants to ensure that necessary housing is developed in a sustainable way. In its new Local Plan, the Council acknowledges that:

> *"Central Bedfordshire's environment is key to its identity and widely valued by our residents, visitors and businesses. […] We also depend on the ecosystem services, which are services provided by the natural environment that benefit people."* (Central Bedfordshire Council, 2018, p. 3)

The plan also makes explicit reference to tools for analysing the impact of development proposals on NC and ESs and the NCPT has the backing of the councillors because it can be used to efficiently assess if a new development contributes positively to NC and the Council's policies for the natural environment.

The NCPT was used to assess all sites proposed for development where at least an initial sketch/draft masterplan was available – 8 sites together.[48] The aims of the assessments were (1) to test if the proposed growth locations are acceptable for development; and (2) to test if the proposed designs were acceptable.

One of the objectives of the Council, as outlined in the Local Plan, is to *"create additional environmental enhancement"* (Central Bedfordshire Council, 2018, p. 4) or 'environmental net-gain' as promoted by Central Government (HM Government, 2018). The locations and designs were assessed against this policy goal.

Findings

For the first test, the acceptability of the sites, the focus was on the minimum/maximum possible scores calculated by the NCPT (Figure 5.10). Less negative minimum possible scores indicate that a site has less NC (to lose) in the first place. Higher positive maximum scores on the other hand indicate that there is greater potential for the site to create and/or enhance NC value. The NCPT outcomes indicated that, in principle, all assessed sites were suitable for development from a NC point of view as all sites offer opportunities for NC enhancement (high maximum possible scores).

[48] The exact sites are not identified due to confidentiality considerations.

Development Impact Score Average Per-Hectare			
Ecosystem Service	Max Possible	Adjusted Scores	Min Possible
1. Harvested Products	+0.2	-2.33	-3.0
2. Biodiversity	+4.6	+0.27	-0.4
3. Aesthetic Values	+6.6	+0.98	-3.4
4. Recreation	+10.0	+4.68	+0.0
5. Water Quality Regulation	+2.3	+0.02	-2.3
6. Flood Risk Regulation	+3.0	+0.51	-0.0
7. Air Quality Regulation	+0.8	+0.11	-0.4
8. Local Climate Regulation	+5.4	+0.79	-2.7
9. Global Climate Regulation	+4.0	-0.32	-1.0
10. Soil Contamination		+0.00	
Development Impact Score		+4.71	

Figure 5.9 Initial NCPT findings for one of the Assessed Sites. The figure shows the results of the NCPT assessment for each assessed ES and aggregated in the DIS. It also indicates the maximum/minimum possible scores the site is capable of delivering.

For the second test, the acceptability of the design, the impact scores (white cells) were the focus. They indicate if the proposed design actually would enhance or deteriorate ESs provision. Here, the outcomes were mixed with most designs having a negative impact on NC and ESs at this stage even if the sites would generally be suitable to provide a positive.

Impact of the NCPT assessments

Central Bedfordshire Council is using the NCPT outcomes to negotiate better designs to achieve 'additional environmental enhancement' for the proposed sites and asked developers to improve their designs towards more positive NC creation. The NCPT has provided the Council with an objective and simple means of assessing both, the location and design of development proposals put forward for consideration.

The Council planners found the NCPT especially useful when working collaboratively with site promotors - negotiating enhancements to masterplans, and giving them a tangible way to measure whether proposals are capable of achieving a net gain in NC. This is meant to ensure that the Council gets the very best out of their sites.

The Council is in the process of re-assessing updated designs with the NCPT. Updated outcomes will then inform the final site allocations. The Council is keen to continue mainstream the value of GI and implementing the NCPT into their everyday planning practice which is seen as an important step towards this goal.

5.5 Discussion

5.5.1 Potential Applications and Benefits of using the NCPT

Drawing on case study experiences and discussions with stakeholders and practitioners, a range of (potential) benefits of using the NCPT could be identified. In its recently published 25 Year Environment Plan, the Government makes a commitment *"to put the environment at the heart of planning and development…"* (HM Government, 2018, p. 32). It can be argued that the NCPT puts 'flesh on the bones' when implementing national and local planning policies because 'what gets measured gets managed', as evidenced through the case study experiences.

NC can tackle many policy priorities such as air quality, public health, climate change etc. in one go as relevant ESs can be delivered from the same land. But so far success was difficult to measure and communicate as ecological impacts are assessed in discrete silos rather than holistically (Baker et al., 2013). The NCPT makes this much easier because it provides an immediate overview of NC impacts in one place and expressed in a quantitative way which is easy to communicate.

The NCPT provides a tangible basis for discussion and negotiations between planning authorities and developers/investors with respect to NC delivery. The quantitative and systematic character of the NCPT can help to clarify exactly what is expected from the developer in terms of NC delivery at the earliest possible stage (outline application). This, in turn, has the potential to speed up the planning process because there is a clearly defined (quantified) goal and a simple way to assess if this goal is likely to be achieved with the proposed design.

One problem often articulated by planning practitioners is that what was initially promised in terms of GI provision at the outline application stage is eroding along the planning process.

With the NCPT, developers can be better held to account for delivering what was promised because the watering down of GI investment further down the line can be objectively measured by the NCPT.

At the operational stage, economic viability is used as a key argument to avoid stronger investment and commitments to implementing better GI as part of development projects (Scott et al., 2017). One can argue that, besides economic viability, development also needs to be socially and environmentally viable (or GI viability as in Scott et al., 2017). The NCPT allows developers to easily communicate NC enhancements to stakeholders, shareholders, customers and regulators through a set of quantitative indicators which can give them a competitive advantage.

I believe that the NCPT will help not only to better mitigate negative effects of planning and development on the environment, but also to enable planning and development to play a more positive role in the provision and enhancement of multifunctional GI that works hard for people and wildlife alike.

5.5.2 Environmental net-gains and the way ahead for the NCPT

The revised National Planning Policy Framework (NPPF) states that: *"Planning policies and decisions should encourage multiple benefits […] to achieve net environmental gains."* (MHCLG, 2018, p. 35). While this is welcome, it also creates an implementation void – how can 'environmental net-gains' be meaningfully operationalised? A particular challenge is measuring success – what do 'environmental net-gains' look like and how can they be measured in practice?

Whilst the Government is yet to define what 'environmental net-gains' exactly means, it will likely be related to the NC performance of new development. This will require some kind of quantification system such as already in place for measuring biodiversity net-gain through the Biodiversity Metric (Natural England, 2019c). Hence, the NCPT is already perfectly positioned to operationalise and implement 'environmental net-gains'. This, in turn, would be a big step towards mainstreaming ecosystem science and GI in the planning system (Scott et al., 2018; Scott and Hislop, 2019), through the lens of NC highlighting its valuable asset character.

The NCPT is work in progress and will be subsequently updated to acknowledge relevant policy changes such as emerging ‘net-gains’ policies (HM Government, 2018; MHCLG, 2018). I am keen to establish the NCPT as ‘environmental net-gains’ tool. Here, I will pursue a standardised approach for implementing net-gains whilst at the same time keeping the NCPT flexible enough to incorporate local differences and policies.

I have received considerable feedback since the release of the NCPT and I am keen to further improve this innovative tool to best suit practitioners. My intention for the future is to make the NCPT more user friendly, linked to policy priorities and other tools, more flexible, and including standards for how good GI delivery looks like to also encourage improvements above and beyond what is legally required and even ‘minimum’ environmental net-gain requirements, should they emerge. I believe that this will be a significant contribution towards truly mainstreaming the asset value of GI into planning policy – in the UK and possibly beyond.

5.5.3 Caveats and Limitations of this Approach

The methodical approach chosen for the development of the NCPT is experimental. This was determined by the nature of this research project – especially reducing the high complexity of ecosystem science to a manageable but still meaningful level. For each assessed ESs a broad range of potential indicators and assessment methods was available. Within scope of this project, only a limited set of indicators could have been implemented which reduces the complexity and data requirements of the tool; but also the accuracy of the outcomes.

Several datasets and indicators have been proposed by task group members that could improve the accuracy of the tool outcomes. But often they could not be adopted because (1) datasets to inform these indicators were difficult to access or only accessible for specific audiences; (2) datasets would need extensive and time-consuming manipulation or interpretation to be useful to inform the NCPT; and (3) data was only available at specific locations but not at the national level.

Furthermore, values are based on expert knowledge and are founded on a science base that still reveals many gaps as not all aspects of NC and ESs are sufficiently well understood. It should also be noted that several task group members stated that they were not certain about the scores they established and that these should be treated as 'best guesses'. For these reasons tool outcomes should be treated as purely indicative. The NCPT is a supplementary information source to assess the impact of proposed developments and plans on NC and ESs and is not designed to replace other elements to be considered for a planning decision such as an Environmental Impact Assessment or a Flood Risk Assessment.

5.6 Conclusions

The research project has shown that expert and stakeholder knowledge can be used successfully to inform a 'fit-for-purpose' tool to systematically assess NC and ESs impacts of developments and their masterplans. There is overall agreement across the involved stakeholders that the NCPT can provide a very valuable additional information source to assess, monitor and manage the impact of proposed plans and developments on NC and ESs in a holistic way; acknowledging that these outcomes are indicative rather than the proven outcome.

The case study trials have revealed that assessments using the NCPT offer a valuable additional perspective on development impacts; beyond the 'tick-box thinking' prevalent in planning decision-making to date. The NCPT is seen by all partners involved as a stepping stone towards integrated management of NC and ESs in a planning context – something that has not been mainstreamed to date.

6 Chapter Six: General Conclusions and Discussion

6.1 Rationale

It is clear that natural capital (hereafter NC) and ecosystem services (hereafter ES) are of significant value and critical importance to our wellbeing, health and economic prosperity (Costanza et al., 1997; Defra, 2017; NCC, 2015; Public Health England, 2017; TEEB, 2010a; UK NEA, 2011b). At the same time many NC assets and the ES they provide are in a degraded state with many continuing to decline; both, in the UK and worldwide (Millennium Ecosystem Assessment, 2005; UK NEA, 2011b).

Drivers for this decline, especially in urban areas such as our case study Birmingham, include land-use change due to development. Worldwide, the population is projected to continue to grow by nearly 2 billion by 2050 and this population growth will almost entirely take place in urban areas (UN, 2019a, 2019b). In the UK alone, the population is expected to grow by 6 million (9%) by 2043 (ONS, 2019c). This growth, combined with cuts to parks and greenspace budgets (HLF, 2016), is likely to add pressure on urban NC and ES.

Another driver for NC decline is that the unregulated market forces often fails to protect and supply especially cultural and regulating ES (Costanza et al., 2014; Daly and Farley, 2011). It is arguable that in such cases of market failure Government institutions need to step in to incentivise the protection and enhancement of NC and ES. To inform decision-making and measure relevant interventions appropriately, a understanding of the value of NC and ES is required (Badura et al., 2017; HM Treasury, 2018; Ling et al., 2018; NCC, 2013; Scott et al., 2014). Whilst more and more valuation evidence is becoming available, there is widespread recognition of an 'implementation gap' between the evidence produced by academia and the evidence demanded to inform practical decision-making (Bastian et al., 2012; Cowling et al., 2008; Daily et al., 2009; Daily and Matson, 2008; Kroll et al., 2012; Laurans et al., 2013; Laurans and Mermet, 2014; Layke, 2009; Levrel et al., 2017; Nahuelhual et al., 2015; Primmer and Furman, 2012; Shi, 2004). My hypothesis was that NC and ES valuation does not yet more widely inform decision-making because relevant valuation evidence is often not fit-for-purpose and available at the right scale where decisions take place.

6.2 Overall Aim and Objectives of this Thesis

The aim of this thesis was to bridge the 'implementation gap' by developing and adapting 'fit-for-purpose' NC and ES valuation tools designed specifically to support decision-making at relevant scales where land-use decisions take place. The objectives were:

1. To provide NC/ES valuation evidence based on and driven by decision-makers' demand;
2. To adopt and develop relevant valuation tools suitable for the relevant decision-making context in Birmingham; and
3. To contextualise how these valuation tools are positioned along stages of the decision-making process and geographical scales.

In the following sections I will outline how these objectives were achieved before concluding how the overall aim of the thesis was delivered.

6.3 The Delivery of Demand-driven Evidence

This investigation has shown that 'fit-for-purpose' NC and ES valuation evidence is demanded by decision-makers; at least in the context of a Birmingham case study. The demand for NC and ES valuation is evidenced by all assessments as part of this thesis being initiated and commissioned by Birmingham City Council rather than funded through research grants, for example. Arguably, this indicates that these assessments were driven by practical demand for NC and ES valuation evidence as Birmingham City Council invested significant time and money to enable this work.

That the main purpose of these valuation exercises was to inform decision-making rather than being a purely academic exercise can also be evidenced by the fact that all assessments were (at least initially) disseminated through research reports and through a practical tool; dissemination media that are more accessible to the decision-makers than for example academic papers (see also Shi, 2004). The ES supply and demand maps (Chapter Two) and Ecosystem Assessment for Birmingham (Chapter Three) were both initiated and commissioned by Birmingham City Council and later published as part of Birmingham's Green Living Spaces Plan (Birmingham City Council, 2013; Hölzinger et al., 2013c, 2013b) which is effectively the Councils Green Infrastructure Strategy. Birmingham's NC Accounts and Health Economic Assessment (Chapter Four) was also initiated and funded by Birmingham City Council and has been first published on the Council's website.[49] And whilst the development of the Natural Capital Planning Tool (NCPT; Chapter Six) was partially funded by the Natural Environment Research Council (NERC; NE/N017587/1); Birmingham City Council was a main initiator and driver for its development and invested significantly in-kind towards its development and testing. Furthermore, it commissioned and funded the application of the NCPT for the Birmingham Langley Urban Extension.

All assessments, apart from the NC Accounts and Health Economic Assessment, also involved a wide range of stakeholders who offered their valuable time in-kind to support these assessments.[50] This also shows the wider support and demand for these kind of valuation exercises and tools as, arguably, they would not invest in them if they would not think they were of value. That this is not limited to Birmingham can be evidenced by the fact that similar valuation exercises have also been demanded and delivered in other areas; often involving stakeholders (see for example Hölzinger, 2019, 2017, 2016a, 2016b, 2015). Overall, it is clearly evidenced that objective 1 'To provide NC/ES valuation evidence based on and driven by decision-makers' demand' has been delivered upon.

6.4 The Adaptation and Development of Valuation Tools for each Specific Decision-Making Context

Principle 2 of the Ecosystem Approach states that *"management should be decentralized to the lowest appropriate level"*.[51] And indeed, most planning and land-use decisions are taken at the local rather than the national or international scale (MHCLG, 2018). Notwithstanding the requirement for NC and ES valuation evidence at the national and international scale, such evidence cannot easily be translated or downscaled to the local or project scale (Burkhard et al., 2012; Haines-Young et al., 2012). A question I often encountered throughout my PhD when working with decision-makers and stakeholders was *'but what does this mean*

[49] https://www.birmingham.gov.uk/downloads/file/13452/birmingham_natural_capital_accounts_-_july_2019 (accessed: 10/12/2019)

[50] The lack of stakeholder involvement for developing the NC Accounts and Health Economic Assessment was not because of a lack of stakeholder support but because of time and budget considerations.

[51] https://www.cbd.int/ecosystem/principles.shtml (accessed: 2nd December 2019)

for us?'. Because relevant evidence at the relevant decision-making scales in Birmingham did not exist, it needed to be created. This required the adaptation of valuation tools or, as in the case of the NCPT, even the creation of a completely new tool.

Because a suitable ES mapping tool that would satisfy Birmingham City Council's requirements to inform its Green Living Spaces Plan (Birmingham City Council, 2013) did not exist, it needed to be developed specifically for the local demand and context. This is why I developed the Multiple Challenge Map for Birmingham (Chapter Two) specifically for the Birmingham context involving relevant stakeholders throughout the process. And whilst a National Ecosystem Assessment (UK NEA, 2011b) already existed and certainly provided inspiration, it did not provide Birmingham City Council with the local evidence it required about the value of Birmingham's ES. To my knowledge the Birmingham Ecosystem Assessment (Chapter Three) was the first city-wide Ecosystem Assessment established; at least in the UK.

The NC Accounts and Health Economic Assessment for Birmingham (Chapter Four) was also innovative as it was one of the first local NC Accounts developed in the UK and the first time Council Tax Uplift due to surrounding greenspace has been quantified. Also notable is that it was the advancement of provisional NC Accounts I developed for the Council before (Hölzinger and Sadler, 2016). To my knowledge these provisional NC were the first NC accounts at the local (city) scale in the UK.

The most innovative exercise within this thesis was the development of the NCPT. This was required because an alternative to effectively assess the benefits of ES in the planning context as called for in the (now revised) National Planning Policy Framework (DCLG, 2012) simply did not exist. The broad support for the development of the NCPT by Local Planning Authorities, government institutions and other stakeholders (see Appendices 5.1 and 5.2) and later uptake by end-users[52] evidences the demand for the NCPT.

Already the great British economist John Maynard Keynes said that *"it is better to be roughly right than precisely wrong."*[53] And that was exactly the aim of these exercises – to be roughly right by getting as close to the true NC and ES value as possible rather than being precisely

[52] See http://ncptool.com/case-studies/ (accessed: 10/12/2019)
[53] Originally: "It is better to be vaguely right than exactly wrong" (Read, 1898)

wrong by ignoring and neglecting value domains that are more difficult to quantify. The purpose of the assessments were to reveal the magnitude of NC value rather than a precise value (see also ONS and Defra, 2017); acknowledging that decisions affecting the environment cannot wait until perfect evidence has been established.

This evidence shows the innovative approach taken to adapt valuation tools to be suitable for the appropriate scale and decision-making context. It also shows that this research improves our understanding of NC and ES values in relevant decision-making contexts and to the academic literature more generally. Overall, this shows that objective 2 of this thesis, 'To adopt and develop relevant valuation tools suitable for the relevant decision-making context in Birmingham' has been met.

6.5 Contextualisation of how Valuation Tools Were Applied in Birmingham

Given that a range of tools was demanded by Birmingham City Council's to inform relevant decisions and policies affecting NC and ES also indicates that there is not one 'magic bullet' valuation tool that is suitable for all circumstances and decision-making contexts (see also Scott et al., 2014). To guide future applications of valuation tools, I am contextualising the adapted and developed valuation tools across stages of the decision-making cycle and geographical scales as applied in Birmingham.

In Section 1.6.1, I outlined a typical decision-making cycle: IDEAS-SURVEY-ASSESS-PLAN-DELIVER-EVALUATE. Whilst it is recognised that decision-making does not necessarily follow these subsequent steps (Scott et al., 2014), it does provide a useful framework for the contextualisation of valuation tools adapted and developed as part of this thesis. While this is a decision-making cycle, it is presented here as a scalar process for the purpose of effective visualisation (Figure 6.1).

Figure 6.1 shows the framework and how NC and ES valuation tools, as applied in Birmingham, inform decision-making across scales and stages. The decisions to be informed are NC interventions on the ground. Here, it is important to note that I only indicate the most relevant stages of the decision-making process intended to be informed by the tools. Whilst the Birmingham Ecosystem Assessment was mainly intended to inform the survey and valuation stages, for example, it is entirely possible that it also informed new ideas for interventions such as through the recognition of the value of certain ES. It is arguable that all valuation tools stated below can play some role across all stages of the decision-making process; also recognising that the lines between the stages are not as clear as indicated below (see also Hölzinger, 2014; Scott et al., 2014). It should also be recognised that the tools can inform decisions at different scales. An Ecosystem Assessment can for example also inform national (UK NEA, 2011b), regional (Hölzinger, 2011) and arguably sub-city decision-making.

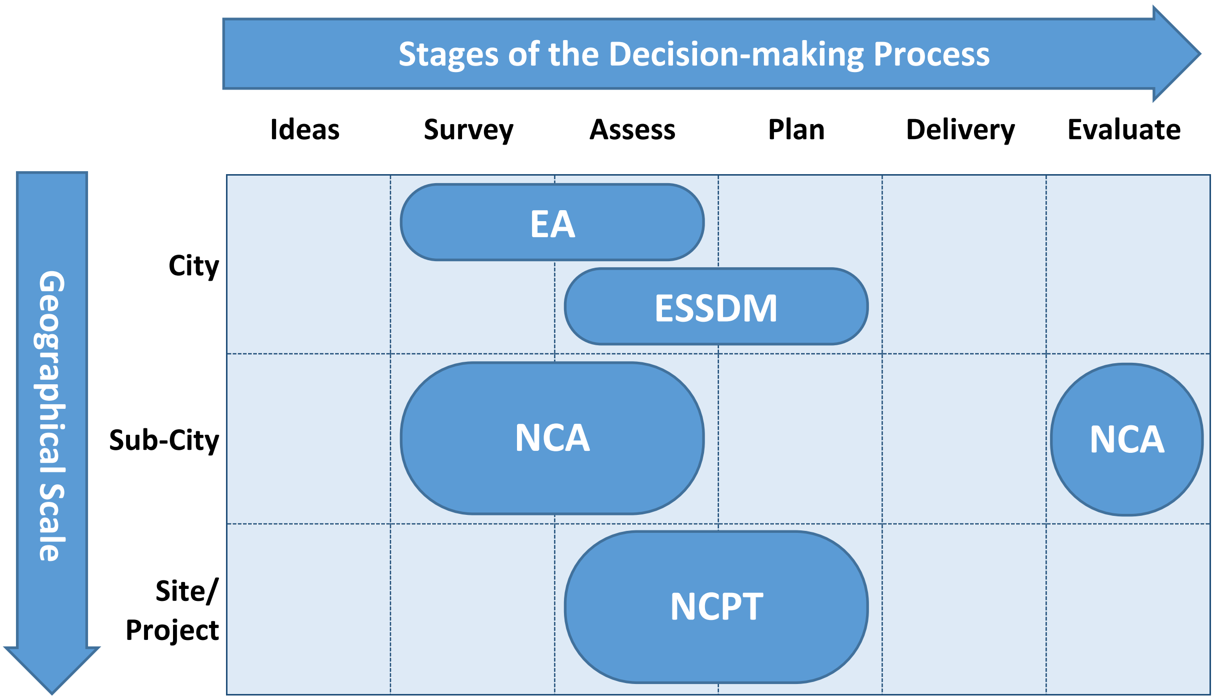

Figure 6.1 Contextualisation of Valuation Tools as Applied in Birmingham. The figure shows at which geographical stages NC and ES valuation tools were applied and which stages of the decision-making process they were mainly intended to inform in Birmingham. The following tools were included: Ecosystem Assessment (EA), Ecosystem Services Supply and Demand Map (ESSDM), Natural Capital Accounting (NCA) and the Natural Capital Planning Tool (NCPT).

<u>Birmingham Ecosystem Assessment</u>

The Ecosystem Assessment for Birmingham has been applied at the city-scale as all identifiable ecosystems in the city were included. The main aim was to produce a robust evidence base of the extent of the city's NC assets (SURVEY) and a better understanding of the value of ES provided by different broad habitat types (ASSESS). The intention was to generate general awareness about the value and importance of the city's ecosystems so that decision-makers take these better into account whenever NC and ES are affected. Hence, further stages of the decision-making process such as planning may also be affected indirectly by better awareness of ES values.

Ecosystem Services Supply and Demand Map (Multiple Challenge Map for Birmingham)

Mainly based on the available evidence at the city-scale (generated as part of the Ecosystem Assessment), the exercise assessed the supply, demand and distribution of ES (ASSESS). The resulting Multiple Challenge Map for Birmingham had two main purposes: to indicate areas where the creation or enhancement of NC might be most beneficial and 'ES hotspots' where NC provides a particularly high level of ES provision. The maps were intended to inform where NC interventions in terms of protection and creation/enhancement would be most beneficial (PLAN).

Birmingham Natural Capital Accounts and Health Economic Assessment

The Birmingham NC Accounts were not conducted for all NC assets in Birmingham but only those managed by Birmingham City Council. Hence, it is a sub-city level assessment. In contrast to the Ecosystem Assessment, the NC Accounts did not aim to identify the value of ES provided by each broad habitat type. This allowed to include additional services and benefits which methodically cannot be attributed to specific habitat types such as for overall greenspace recreation and health benefits. This generated a new evidence base for Council-managed NC assets (SURVEY). It also provided a detailed assessment of the NC value to society, the Council and in health benefits (ASSESS). Because these NC Accounts also include a Cost-Benefit Analysis (CBA) element by comparing management costs (liabilities) and NC benefits (assets), it also served to evaluate the net-benefits of the Councils investment in its NC assets (EVALUATE).

Natural Capital Planning Tool (NCPT)

Here, I do not assess which stages of the decision-making process the NCPT informs more generally, but which stages it informed when applied for the Birmingham Langley Sustainable Urban Extension. The NCPT was specifically applied to assess the impact of the Masterplan on ES provision (ASSESS). This informed the revision of the Masterplan (PLAN). While, in other cases, this would also be likely to inform the delivery and evaluation stages of planning decisions, this was not the case here because the final masterplan was not assessed with the NCPT again.

Overall, the application of different NC and ES valuation tools across stages of the decision-making process and relevant scales shows that a variety of tools is required to inform decision-making and satisfies objective 3 of this thesis: 'To contextualise how valuation tools inform decision-making along stages and geographical scales'.

6.6 Practical Implications: Towards Demand-driven 'Fit for Purpose' Ecosystem Valuation

This thesis has shown that 'fit-for-purpose' NC and ES valuation evidence to inform relevant decisions can be delivered; at least in the case of Birmingham. A range of recommendations can be drawn from the experiences and lessons learnt from this journey:

First, decision-makers should not be left alone expecting them to identify and use general valuation evidence themselves to inform their decisions. This is why researchers need to directly engage with them and translate complex ecosystem science into readily accessible evidence and tools. This can be achieved if they are provided with specific guidance (see for example Hölzinger, 2014 for guidance on how Ecosystem Assessments should be used in the UK) and actively engaged in the process of generating this evidence. It also means that decision-makers and practitioners need to be equipped with the necessary time, resources and expertise to enable them to create, understand and apply NC and ES valuation evidence; together with the research community. Often, decisions and policies need to be made rather quickly which means that the long application and decision timescales for research grants are not necessarily suitable. Also, whilst tailor-made assessments such as Natural Capital Accounts may be appropriate for large-scale projects, the everyday work of the decision-makers, for example within local planning authorities, is dominated by small-scale proposals such as the development of few dwellings. Whilst the environmental impact of each development may be limited, the cumulative effect of small-scale development projects can be significant. Decision-makers usually have very limited time and resources to inform themselves about the value trade-offs inherent in such decisions. Especially to inform such 'day-to-day' decisions, decision-makers need to be equipped with 'fit-for-purpose' valuation tools such as the NCPT that are specifically designed for their practical circumstances they find themselves in.

Secondly, it is important that the NC and ES valuation research is driven by the end-user demand; the decision-makers and practitioners. The aims and objectives of NC and ES valuation research should be developed and defined together with the end-user of the evidence rather than based on what researchers thinks would be demanded or what is comparatively easy to investigate which is then ‘dropped’ at the decision-maker hoping for the best. Rooting research in the decision-maker demands ensures that the evidence provided is ‘fit-for-purpose’ to inform their decision to hand (see also Dunford et al., 2018; Fisher et al., 2009). The engagement of stakeholders throughout the process is also advised so that evidence also services their requirements (Bastian et al., 2012; Raum, 2018). If stakeholders are left out of the process, they may not accept the provided evidence and therefore the decisions based on that evidence.

Thirdly, evidence needs to be generated for the relevant geographical scales where land-use decisions take place (Chan et al., 2006). Decisions affecting ecosystems are made at all institutional hierarchy levels from the international to the individual level (Hein et al., 2006). NC and ES valuation evidence such as at the national level (UK NEA, 2011b) generates general awareness and recognition at the local level but is less valuable to inform specific decisions ‘on the ground’. This is because findings cannot easily be downscaled, sufficiently rationalised and operationalised at the local scale where land-use decisions take place (see also Burkhard et al., 2012; Chan et al., 2006). Here, scale-specific NC and ES valuation can help to make trade-offs between benefits of NC assets and other policy priorities such as housing and economic growth explicit (Primmer and Furman, 2012; Scott et al., 2017).

Fourthly, NC and ES valuation evidence needs to be provided and presented in a format and terminology that is accessible and relevant to the relevant decision-makers (Fish, 2011; Paetzold et al., 2010). Here, transaction costs for identifying, accessing, reviewing and operationalising evidence requires specific attention (Daly and Farley, 2011). Given that decision-makers do not regularly review the latest academic evidence to inform their decisions, also because of time and resource constraints (Chan et al., 2006), the publication of relevant evidence in academic papers is less useful in this context. Here, it is more useful to provide evidence in a terminology adopted to the language used by the relevant target audience. It is also important to provide the evidence in a relevant format and place where it is easily accessible to the target audience. This has been achieved for example for the

Birmingham Ecosystem Assessment and ES supply and demand maps by appending them directly to the relevant policy - Birmingham's Green Living Spaces Plan (Birmingham City Council, 2013).

Finally, it is important to explicitly outline relevant assumptions and limitations of valuation evidence (see also Scott et al., 2017). Despite significant efforts by the research community to improve both; ecological baseline data and valuation evidence, there are still significant gaps in the evidence base. This means that NC and ES valuation can only capture a proportion of the total NC and ES value (see also Sunderland et al., 2019). Translating complex science into accessible formats should not be an excuse for neglecting these. In the end decisions always need to be made with a degree of uncertainty. But at least these uncertainties should be made explicit so that decision-makers can take them into account. Ideally, they are integrated in the assessment such as through sensitivity analysis as the case in the Birmingham Ecosystem Assessment.

To mitigate some of these limitations, further research is required to improve NC and ES baseline data which valuation is based on. It is also important to further improve relevant indicators so that tools like the NCPT can be based more on published evidence rather than expert opinion which will strengthen confidence in generated scores and outcomes. Further research on disentangling the monetary value biodiversity adds to NC and ES would also be beneficial given that biodiversity is already well integrated in for example the UK planning system (MHCLG, 2018)[54].

Last but not least, further research is required on whether ES should be discounted at the same rate as man-made goods and services given the very significant impact the discount rate has on ES valuation; especially when assessed over long timescales (see also Scott et al., 2014). One research question here is whether the multifunctional ES values generated over millions of years through evolution can be substituted for by technological progress. Whilst technological progress may significantly improve certain ES values such as in the case in food production, this is less obvious for others. It could be questioned, for example, if the total value of the multifunctional ES provided by trees can be substituted for (or significantly

[54] Also https://www.gov.uk/government/news/spring-statement-2019-what-you-need-to-know (accessed: 07/12/2019)

enhanced in terms of productivity) by technological progress anytime soon. If not, then this element of the discount rate may not be justified for ES and NC. Further advancements in these areas of research will help to improve valuation tools as outlined in this thesis; and ultimately enable better informed decision-making whenever the environment is affected.

7 References

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Appendices

Appendix 2.1: Birmingham Ecosystem Assessment Steering Group Members

Jaqueline Ashdown	National Health Service
Sara Carvalho	EcoRecord
Rachel Curzon	Birmingham City University
Nicola Farrin	Birmingham City Council
Chris Parry	The Wildlife Trust for Birmingham and the Black Country
Amanda Patterson	Environment Agency
Kyle Stott	National Health Service
Tim Sunderland	Natural England
Emma Woolf	Friends of Cotteridge Park

Appendix 3.1: Multiple Challenge Map for Birmingham Steering Group Members

Simon Atkinson	Birmingham and the Black Country Wildlife Trust
Sara Cavalho	EcoRecord
Rod Chapman	Birmingham City Council
Rachel Curzon	Birmingham City University
Martin Eade	Birmingham City Council
Jeff Edwards	Natural England
Nicola Farrin	Birmingham City Council
Jane Field	Environment Agency
William Groves	Environment Agency
Michael Hardman	Birmingham City University
Sarah Hepburn	Business Council for Sustainable Development UK
Michelle Howard	National Health Service
Dave Huges	Environment Agency

James Kitchen	Environment Agency
Graham Lennard	Birmingham City Council
Hayley Pankhurst	Natural England
Chris Parry	Birmingham & Black Country Wildlife Trust
Antony Ratcliffe	Natural England
Richard Rees	Birmingham City Council
Andy Slater	EcoRecord
Kyle Stott	National Health Service
Emma Woolf	Birmingham Open Spaces Forum

Appendix 3.2: Multiple Challenge Map for Birmingham Expert Group Members

Biodiversity

Simon Atkinson	Birmingham & Black Country Wildlife Trust
Sara Cavalho	EcoRecord
Richard Coles	Birmingham City University
Andy Crawford	Environment Agency
Nicola Farrin	Birmingham City Council
Nick Grayson	Birmingham City Council
Chris Greziok	Environment Agency
Theresa Haddon	West Midlands Foodlinks
Chris Parry	Birmingham & Black Country Wildlife Trust
Jon Sadler	University of Birmingham
Andy Slater	EcoRecord
Ian Trueman	University of Wolverhampton
Dan Van der Horst	University of Birmingham

Recreation/Aesthetic Values & Sense of Place/Education

Jenny Colfer	Health Protection Agency

Richard Coles	Birmingham City University
Lorraine Cookson	Birmingham City Council
Nick Grayson	Birmingham City Council
Theresa Haddon	West Midlands Food Links
Michelle Howard	National Health Service
Peter Lee	University of Birmingham
Graham Lennard	Birmingham City Council
Chris Parry	Birmingham & Black Country Wildlife Trust
Jon Sadler	University of Birmingham
Miles Tight	University of Birmingham
Dan Van der Horst	University of Birmingham
Verity Watson	University of Aberdeen
Emma Woolf	Birmingham Open Spaces Forum

<u>Local Climate Regulation/Air Quality Regulation</u>

Andy Baker	National Health Service
Jenny Colfer	Health Protection Agency
Xiaoming Cai	University of Birmingham
Lee Chapman	University of Birmingham
Richard Coles	Birmingham City University
Juana-Maria Delgado	University of Birmingham
Paul Fisher	Health Protection Agency
Nick Grayson	Birmingham City Council
Dave Huges	Environment Agency
Rob MacKenzie	University of Birmingham
Ruth Meek	Environment Agency
Richard Rees	Birmingham City Council
Charles Story	Environment Agency
Kyle Stott	National Health Service

Mamoona Tahir	Health Protection Agency
Mark Wolstencroft	Birmingham City Council
Shawn Woodcock	Health Protection Agency

Flood Risk Mitigation

Matt Ashworth	Environment Agency
Keith Boyle	Environment Agency
John Bridgeman	University of Birmingham
Cynthia Carliell-Marquet	University of Birmingham
Sara Cavalho	EcoRecord
Pete Clarke	Environment Agency
Richard Coles	Birmingham City University
Rob Ellis	Environment Agency
Chris Farmer	Environment Agency
Jane Field	Environment Agency
Nick Grayson	Birmingham City Council
Christopher Grzesiok	Environment Agency
Dave Huges	Environment Agency
Fiona Keates	Environment Agency
Xiaonan Tang	University of Birmingham
David Thrussell	Environment Agency
Kerry Whitehouse	Birmingham City Council
Clive Wright	Birmingham City Council

Weighting Exercise Participants

Chloe Bellamy	Durham Wildlife Trust
Christopher Boyko	Lancaster University
Sara Carvalho	EcoRecord
Lee Chapman	University of Birmingham

Stewart Clarke	Natural England
Jenny Colfer	Health Protection Agency
Iain Diack	Natural England
Jeff Edwards	Natural England
Nicola Farrin	Birmingham City Council
Paul Fisher	Health Protection Agency
Nick Grayson	Birmingham City Council
Theresa Haddon	West Midlands Food Links Ltd
James Hale	University of Birmingham
Michael Hardman	Birmingham City University
Dave Hughes	Environment Agency
Cooper Imagination	Lancaster University
Rob MacKenzie	University of Birmingham
Chris Parry	Birmingham & Black Country Wildlife Trust
Antony Ratcliffe	Natural England
Richard Rees	Birmingham City Council
Andy Slater	EcoRecord
Derrick Taylor	Birmingham City Council
Ian Trueman	University of Wolverhampton
Shawn Woodcock	Birmingham City Council
Emma Woolf	Birmingham Open Spaces Forum
Xiao Nan	University of Birmingham

Appendix 5.1: NCPT Steering Group Members

Phase 1: NCPT development (2014-2015)

Chris Baggott	Birmingham City Council
Sarah Bentley	Staffordshire County Council
Amanda Craig	Natural England
Diane Crowe	Carillion plc
Nick Grayson	Birmingham City Council

Thomas Hartmanshenn	Frankfurt City Council
Pat Laughlin	UK Business Council for Sustainable Development
Jeremy Parker	Fira
Chris Parry	Birmingham & Black Country LNP
Tim Pickering	Environment Agency
Jon Sadler	University of Birmingham
Nigel Sagar	Skanska
Alister Scott	Birmingham City University

Phase 2: Testing and injection phase (2016-2018)

Paul Arnold	Skanska
Dave Barlow	Manchester City Council
Dave Biss	Solihull Metropolitan Borough Council
Judy Clavery	Lake District National Park Authority
Charles Cowap	Royal Institution of Chartered Surveyors
Mike Eastwood	Solihull Metropolitan Borough Council
Chris Fairbrother	South Downs National Park Authority
Nicola Farrin	Birmingham City Council
Nick Grayson	Birmingham City Council
Dawn Griffiths	Natural England
Richard Hammerton	Shropshire County Council
Thomas Harle	Natural England
James Harris	Royal Town Planning Institute
Michael Harris	Royal Town Planning Institute
Chris Hayes	Skanska
Sally Hayns	CIEEM
Max Heaver	Defra
Bruce Howard	Ecosystem Knowledge Network
Roy Hymas	Natural England
Sarah Jackson	Bath & North East Somerset Council
Allison Jean	Environment Agency
Alastair Johnson	Defra
Emma Johnson	Natural England
Laura Kitson	Central Bedfordshire Council

Pat Laughlin	Midlands Environment Business Company
Paul Leinster	Cranfield University
Jason Longhurst	UK BCSD
Robin Mager	Shropshire Wildlife Trust
Andrew Marsh	Central Bedfordshire Council
Peter Massini	Greater London Authority
Dave McCabe	Tarmac
Lindsay McCulloch	Southampton City Council
Rosie McEwing	Urban Green
Stephen Mooring	Central Bedfordshire Council
Enrique Moran Montero	Tarmac
Lexie Munro	CIEEM
Krista Patrick	Greater Manchester Combined Authority
Kelly Porter	South Downs National Park Authority
Lizzie Rendell	Skanska
Jim Rouquette	Natural Capital Solutions
Chris Saville	Environment Agency
Tim Slaney	South Downs National Park Authority
Alison Smith	University of Oxford
Colin Smith	Defra
Tim Sunderland	Natural England
Ruth Waters	Natural England
Dan Wrench	Shropshire County Council

All steering group members are listed in alphabetic order.

Appendix 5.2: NCPT Task Group Members (2014-2015)

Mike Ashmore	University of York
Julia Banbury	Staffordshire County Council
Emily Barker	Worcestershire County Council
Richard Bassett	University of Birmingham
Steve Bloomfield	Worcestershire Wildlife Trust
William Bloss	University of Birmingham
Richard Brandsma	Environment Agency
Paul Burns	Birmingham City Council

Xiaoming Cai	University of Birmingham
Ewan Calcott	Forestry Commission
Sara Carvalho	EcoRecord
Jamie Cooper	Staffordshire County Council
Ron Corstanje	Cranfield University
Ali Glaisher	Staffordshire County Council
Nick Grayson	Birmingham City Council
Alex Hale	Environment Agency
James Hale	University of Birmingham
Michael Hardman	University of Salford
Joe Hayden	Birmingham City Council
Julie Holloway	Natural England
Dan Van der Horst	University of Edinburgh
Safieh Javadinejad	University of Birmingham
Cédric Laizé	Centre for Ecology & Hydrology
Susan Lee	University of Birmingham
Alex McDonald	Environment Agency
Ruth Meek	Environment Agency
Rachel Melvin	Staffordshire County Council
Justin Milward	Woodland Trust
Simon Needle	Birmingham City Council
Chris Parry	Birmingham & Black Country Local Nature Partnership
Tippala Gamage Perera	University of Birmingham
Tim Pickering	Environment Agency
John Porter	Birmingham City Council
Gary Rogerson	Skanska
Gina Rowe	Warwickshire Wildlife Trust
Jon Sadler	University of Birmingham
Nigel Sagar	Skanska
Lee Southall	Birmingham City Council
Xiaonan Tang	University of Birmingham
Sam Todd	Environment Agency
Vicky West	Forestry Commission
Martyn Wilson	Worcestershire County Council

Harriet Wood	Small Woods
Lucy Wood	Worcestershire Wildlife Trust
Julian Wright	Environment Agency

All task group members are listed in alphabetic order.

Appendix 5.3: NCPT Land-Use Classification Framework

A	**Woodland and scrub**
A.1	Woodland
A.1.a	Lowland beech and yew woodland (UK BAP Priority Habitat)
A.1.b	Wet woodland (UK BAP Priority Habitat)
A.1.1	Broadleaved woodland
A.1.1.1	Broadleaved woodland - semi-natural
A.1.1.1.a	Broadleaved ancient semi-natural woodland (ASNW)
A.1.1.1.b	Upland birchwoods (UK BAP Priority Habitat)
A.1.1.1.c	Lowland mixed deciduous woodland (UK BAP Priority Habitat)
A.1.1.1.d	Other broadleaved woodland - semi-natural
A.1.1.2	Broadleaved woodland - plantation
A.1.1.2.a	Broadleaved plantation on ancient woodland site (PAWS)
A.1.1.2.b	Traditional Orchards (UK BAP Priority Habitat)
A.1.1.2.c	Other broadleaved woodland - plantation
A.1.1.a	Upland mixed ashwoods (UK BAP Priority Habitat)
A.1.1.b	Upland oakwood (UK BAP Priority Habitat)
A.1.2	Coniferous woodland
A.1.2.1	Coniferous woodland - semi-natural
A.1.2.1.a	Coniferous ancient semi-natural woodland (ASNW)
A.1.2.1.b	Other coniferous woodland - semi-natural
A.1.2.2	Coniferous woodland - plantation
A.1.2.2.a	Coniferous plantation on ancient woodland site (PAWS)
A.1.2.2.b	Other coniferous woodland - plantation
A.1.3	Mixed woodland
A.1.3.1	Mixed woodland - semi-natural
A.1.3.1.a	Mixed ancient semi-natural woodland (ASNW)
A.1.3.1.b	Native pine woodlands (UK BAP Priority Habitat)
A.1.3.1.c	Other mixed woodland - semi-natural
A.1.3.2	Mixed woodland - plantation
A.1.3.2.a	Mixed plantation on ancient woodland site (PAWS)
A.1.3.2.b	Other mixed woodland - plantation
A.2	Scrub
A.3	Parkland/scattered trees
A.3.a	Wood-pastures and parkland (UK BAP Priority Habitat)
A.3.1	Broadleaved Parkland/scattered trees
A.3.2	Coniferous Parkland/scattered trees

A.3.3 Mixed Parkland/scattered trees
A.4 Recently felled woodland
B Grassland and marsh
B.1 Acid grassland
B.1.a Lowland dry acid grassland (UK BAP Priority Habitat)
B.1.b Other acid grassland
B.2 Neutral grassland
B.2.a Lowland meadow (UK BAP Priority Habitat)
B.2.b Upland hay meadow (UK BAP Priority Habitat)
B.2.c Other neutral grassland
B.3 Calcareous grassland
B.3.a Lowland calcareous grassland (UK BAP Priority Habitat)
B.3.b Upland calcareous grassland (UK BAP Priority Habitat)
B.4 Improved grassland
B.5 Marsh/marshy grassland
B.5.a Coastal and floodplain grazing marsh (UK BAP Priority Habitat)
B.5.b Other marsh/marshy grassland
B.6 Poor semi-improved grassland
B.a Purple moor grass and rush pastures (UK BAP Priority Habitat)
J.1.2 Amenity grassland
C Tall herb and fern
C.1 Bracken
C.2 Upland species-rich ledges
C.3 Other tall herb and fern (ruderal and non-ruderal)
D Heathland
D.a Lowland heathland (UK BAP Priority Habitat)
D.b Upland heathland (UK BAP Priority Habitat)
D.c Other heathland
D.d Mountain heaths and willow scrub (UK BAP Priority Habitat)
D.e Lowland heathland/dry acid grassland mix (UK BAP Priority Habitat)
D.f Other Heathland/acid grassland mix
E Mire
E.1 Bog
E.1.a Blanket bog (UK BAP Priority Habitat)
E.1.b Lowland raised bog (UK BAP Priority Habitat)
E.1.c Other bog
E.2 Flush and spring
E.3 Fen
E.3.a Lowland fens (UK BAP Priority Habitat)
E.3.b Other fens
E.a Upland flushes, fens and swamps (UK BAP Priority Habitat)
E.4 Peat - bare
F Swamp, marginal and inundation
F.1 Swamp
F.1.a Reedbeds (UK BAP Priority Habitat)

E.a	Upland flushes, fens and swamps (UK BAP Priority Habitat)
F.1.b	Other Swamp
F.2	Marginal and inundation
G	**Open water**
G.1	Standing water
G.1.1	Standing water - eutrophic (UK BAP Priority Habitat)
G.1.a	Canals
G.1.b	Reservoirs
G.1.c	Lakes
G.1.c.a	Mesotrophic lakes (UK BAP Priority Habitat)
G.1.c.b	Oligotrophic and dystrophic lakes (UK BAP Priority Habitat)
G.1.c.c	Other lakes
G.1.d	Ponds
G.1.d.a	Ponds (UK BAP Priority Habitat)
G.1.d.b	Other ponds
G.1.e	Aquifer fed naturally fluctuating water bodies (UK BAP Priority Habitat)
G.2	Running water
G.2.a	Rivers (UK BAP Priority Habitat)
G.2.b	Streams
H	**Coastland**
H.1	Intertidal
H.1.1	Intertidal - mud/sand
H.1.1.a	Intertidal mudflats (UK BAP Priority Habitat)
H.1.1.b	Other intertidal - mud/sand
H.1.2	Intertidal - shingles/cobbles
H.1.3	Intertidal - boulders/rocks
H.2	Saltmarsh
H.2.a	Costal saltmarsh (UK BAP Priority Habitat)
H.2.b	Other saltmarsh
H.3	Shingle above high tide mark
H.3.a	Coastal vegetated shingle (UK BAP Priority Habitat)
H.3.b	Other shingle above high tide mark
H.4	Boulders/rocks above high tide mark
H.5	Strandline vegetation
H.6	Sand dune
H.6.a	Coastal sand dunes (UK BAP Priority Habitat)
H.6.b	Other sand dune
H.8	Maritime cliff and slope (UK BAP Priority Habitat)
H.a	Saline lagoons (UK BAP Priority Habitat)
I	**Exposure and waste**
I.a	Calaminarian grasslands (UK BAP Priority Habitat)
I.b	Inland rock outcrop and scree habitats (UK BAP Priority Habitat)
I.1	Natural rock exposure and waste
I.1.1	Inland cliff
I.1.2	Scree

I.1.3	Limestone pavement (UK BAP Priority Habitat)
I.1.4	Other rock exposure
I.1.5	Cave
I.2	Artificial rock exposure and waste
I.2.1	Quarry
I.2.2	Spoil
I.2.3	Mine
I.2.4	Refuse-tip
J	**Miscellaneous**
J.a	Open mosaic habitats on previously developed land
J.1	Cultivated/disturbed land
J.1.1	Cultivated/disturbed land - arable
J.1.1.a	Arable fields
J.1.1.b	Arable field margins (UK BAP Priority Habitat)
J.1.1.c	Horticulture
J.1.1.c.a	Allotments
J.1.1.c.b	Other horticulture
J.1.2	Cultivated/disturbed land - amenity grassland
J.1.3	Cultivated/disturbed land - ephemeral/short perennial
J.1.4	Introduced shrub
J.2	Boundaries & Hedges
J.2.a	Hedgerows
J.2.a.a	Hedgerows (UK BAP Priority Habitat)
J.2.a.b	Other hedgerows
J.2.5	Wall
J.2.6	Dry ditch
J.2.8	Earth bank
J.3	Built-up areas (incl. streets, gardens etc.)
J.3.a.a	Built-up areas - high density
J.3.a.b	Built-up areas - medium density
J.3.a.c	Built-up areas - low density
J.3.4	Caravan site
J.3.5	Artificial sea wall
J.3.6	Buildings
J.3.6.a	Buildings - area covered with green roof
J.3.6.b	Buildings - area covered with brown roof
J.3.6.c	Buildings - green walls
J.3.6.d	Buildings - Other
J.3.b	Roads
J.3.b.a	Local grey roads (unclassified roads without green features)
J.3.b.b	Grey connection roads (B- and C-roads without green features)
J.3.b.c	Major grey roads (Motorways and A-roads without green features)
J.3.b.d	Local green roads (unclassified roads with green features)
J.3.b.e	Green connection roads (B- and C-roads with green features)
J.3.b.f	Major green roads (Motorways and A-roads with green features)

J.3.c	Street trees and other trees in paved areas
J.3.d	Paved areas (e.g. car parks)
J.3.e	Gardens
J.4	Bare ground