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Geography and Environmental Science

Money Doesn't Grow on Trees: How to Increase Funding for the Delivery of Urban Forest Ecosystem Services?

by

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Abstract

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Urbanisation and a changing climate are leading to more frequent and severe, and less predictable, flood, extreme heat, and air pollution episodes in cities around the world. Green infrastructure can help mitigate these urban problems by providing regulating ecosystem services such as stormwater attenuation, heat amelioration, and air purification. Despite this, nature-based solutions are not yet mainstream in urban planning, local government budgets for tree planting and green space maintenance have declined worldwide, and the extent to which urban forests in particular are planned and managed with ecosystem services delivery in mind has not been researched. A possible way of increasing funding for the delivery of urban ecosystem services is through a targeted beneficiary pays model, i.e. a business- or citizen-financed 'payments for ecosystem services' scheme. However this potential funding mechanism has not been sufficiently researched in an urban context, and it is unclear how public values and uncertainty in the delivery of ecosystem services might be accounted for. This thesis uses a mixed methods approach with different stakeholder groups to help address these research gaps and inform local and national government decision-making.

The overarching aim of the thesis is to establish whether a public-private urban forest PES scheme could be a feasible approach for addressing the constraints to delivery of ES in cities. This research is presented via three separate, but related empirical chapters, using the UK as a case study. The first uses in-depth interviews with local government tree officers from 15 cities to identify the constraints and opportunities for enhancing provision of urban forest regulating ecosystem services. The second empirical chapter uses questionnaire-based interviews with 30 businesses of varying sizes and sectors from the city of Southampton to identify their motivations for, and conditions of involvement in, an urban forest payments for ecosystem services scheme. The third empirical chapter uses a discrete choice experiment with 362 Southampton citizens to determine their willingness-to-pay for urban forest ecosystem services, and specifically, whether this is affected by the uncertainty surrounding ecosystem services provision.

The core finding of this thesis is that a public-private partnership between local governments, businesses and citizens holds strong potential for improving both appreciation of, and financial support for, urban forests. The tree officers were keen to explore a beneficiary-pays approach, whilst both businesses and citizens were in support of contributing to the urban forest, particularly for air purification. However, despite the presence of moral motivations, most businesses would prefer to contribute on a voluntary basis for marketing and corporate social responsibility purposes. Moreover, citizen willingness-to-pay is higher when they are aware of urban forest ecosystem services and the uncertainties surrounding their provision, than when these benefits are seemingly assured, but poorly understood.

This thesis is the first known study to investigate: the integration of regulating ecosystem services into urban forest planning and management (outside of North America); the attitudes of businesses towards investing in urban forest ecosystem services; and whether providing information on the uncertainty surrounding provision of these services can increase willingness-to-pay amongst citizens. As a result, this thesis provides original insights into the potential for a beneficiary-funded urban forest payments for ecosystem services scheme, with implications both for government policy, and on-the-ground urban forest planning, management and governance.

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Academic Thesis: Declaration of Authorship

I, Helen J. Davies

declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

Money doesn't grow on trees: How to increase funding for the delivery of urban forest ecosystem services?

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. Parts of this work have been published as:
    i. Davies, H.J., Doick, K.J., Hudson, M.D. and Schreckenberg, K. (2017) Challenges for tree officers to enhance the provision of regulating ecosystem services from urban forests. *Environmental Research*, 156, 97-107.
    ii. Davies, H.J., Doick, K.J., Hudson, M.D., Schaafsma, M., Schreckenberg, K. and Valatin, G. (2018) Business attitudes towards funding ecosystem services provided by urban forests. *Ecosystem Services*, 32, 159-169.

Signed: .....

Date: 24th November 2019.....

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Abbreviations

ASC	Alternative-specific constant
CCERA	Climate Change, Environment and Rural Affairs
CLES	Centre for Local Economic Strategies
CSR	Corporate social responsibility
CV	Contingent valuation
DCE	Discrete choice experiment
EC	European Commission
ERGO	Ethics and Research Governance Online
ES	Ecosystem service(s)
ESRI	Environmental Systems Research Institute
EU	European Union
EUT	Expected utility theory
FAO	Food and Agriculture Organisation
FWAC	Forestry and Woodlands Advisory Committee
GDPR	General Data Protection Regulation
GIS	Geographic information system
IUCN	International Union for the Conservation of Nature
MEA	Millennium Ecosystem Assessment
NO_2	Nitrogen dioxide
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
PES	Payments for ecosystem services
RQ	Research Question
SPSS	Statistical Package for the Social Sciences
SQ	Status quo
TEEB	The Economics of Ecosystems and Biodiversity
TWT	The Wildlife Trusts
TWIST	Trees and Woods in Scottish Towns
UK	United Kingdom
UK NEA	United Kingdom National Ecosystem Assessment
US	United States
USDA	United States Department of Agriculture
WTP	Willingness-to-pay

Chapter 1 Introduction

Urban forests and other green infrastructure can be an effective nature-based solution to urban problems such as surface water flooding, heat islands, and poor air quality through the regulating ecosystem services that they provide. But the extent to which they can achieve this is dependent on decision-makers taking an ecosystem services approach to urban planning in general, and urban forest management in particular – a paradigm shift that is not yet mainstream. This thesis provides a critique of the current silo, short-term, habitual and reactive approach to urban planning and urban forest management, finding that local authority tree officers could do a lot more to address these urban problems if they had the support of politicians, citizens and businesses. The research therefore investigates the potential for enhancement of urban forest ecosystem services through a proactive, partnership approach that brings in additional funding and support from businesses and citizens (understood here as members of the public).

The rest of this chapter introduces the related concepts of urban forests, green infrastructure, nature-based solutions and ecosystem services; discusses the current academic knowledge regarding the notions of valuation, funding, values, and uncertainty in relation to environmental decision-making; presents the problem that this thesis seeks to investigate and address; sets out the aim and objectives, including the methods chosen to address these; and finally, describes the structure of this thesis. This includes a review of the literature relating to the thesis objectives; the findings of the research (set out as three separate papers); and concluding thoughts on the implications of the findings for policy, practice and research. Four appendices follow: **Appendix A** describes the researcher's achievements during the course of the research (including published papers, and conference presentations); **Appendix B** provides the supplementary material to the first paper; **Appendix C** provides the supplementary material to the second paper; whilst **Appendix D** provides the supplementary material to the third paper (note that this final paper is not yet published).

1.1 Conceptual context to the thesis

1.1.1 Urban environmental problems

The world's towns and cities are growing, both in terms of area and population. From 34% in 1960, the proportion of the world's population living in urban areas exceeded that in rural areas for the first time in 2008, and is expected to reach 60% by 2030 (UNFPA, 2007; The World Bank, 2018). The proportion of urban dwellers is particularly high in developed countries, with 83% in

the UK, 82% in the United States, and 75% in the EU (The World Bank, 2018). This rising urban population has been accommodated primarily through urban sprawl, though urban densification tends to be the preferred planning policy approach as compact cities are seen as more sustainable (Urban Task Force, 1999; UNFPA, 2007). However, a review by Haaland and van den Bosch (2015) found growing evidence worldwide for the loss of urban green space due to densification processes – especially for Asian and Australian cities, and to a lesser degree in Europe and North America. As cities become more densely developed, the increase in built surfaces and corresponding loss of urban greenspace exacerbates the risk of flooding and urban heat island effects (Dallimer *et al.*, 2011; Lemonsu *et al.*, 2015; Miller and Hutchins, 2017). Air pollution is also a problem in many densely populated cities (largely due to a concentration of vehicles), particularly in more deprived areas (Netcen, 2006; Bodnaruk *et al.*, 2017).

Urban environmental problems are further exacerbated by an unpredictable and changing climate. As stated by the IPCC (2014), the Earth's surface has been growing warmer in each of the last three decades, whilst "the period from 1983 to 2012 was likely the warmest 30-year period of the last 1400 years in the Northern Hemisphere" (p.2). Meanwhile, precipitation in the Northern Hemisphere has been increasing since 1901, affecting water resources in terms of quantity and quality (IPCC, 2014). Extreme weather events such as heat waves, droughts, floods, cyclones and wildfires have also become more frequent since around 1950. Within Europe, cities and their inhabitants are already suffering from flood damage and premature death from heat, with climate change expected to have profound impacts on a wide range of city functions, infrastructure and services, as well as human health and well-being (European Environment Agency, 2016a). Similar impacts and future trends are apparent in North America, with communities and the economy expected to be adversely affected over the coming century (US Global Change Research Program, 2018). Influenced by local meteorological conditions, air pollution is also forecast to be an increasing public health concern as the climate warms (De Sario *et al.*, 2013), with ozone pollution on hot days shown to have a significant impact on respiratory mortality (Pattenden *et al.*, 2010).

1.1.2 Nature-based solutions

Urban problems such as surface water flooding, heat islands, and poor air quality have traditionally been tackled via engineering and policy solutions such as expanding sewer capacity, installing air conditioning, or encouraging the use of low-emission vehicles. However, such measures are unlikely to be sufficient as urbanisation, densification and climate change impacts continue into the future. Following many years of research, urban nature is increasingly being promoted as a cost-effective, multifunctional solution to these problems – either alone or in conjunction with engineering and policy solutions (Baró *et al.*, 2015; European Commission,

2015). A range of related terms have emerged in the literature to describe such applications of urban ecosystems – in chronological order, these include urban forests, ecosystem services, green infrastructure and, most recently, nature-based solutions (Escobedo *et al.*, 2019). These are defined, in turn, below.

Urban forests are defined as “all forest and tree resources in (and close to) urban areas" (Konijnendijk, 2003: 177). This includes single trees (such as those found in civic areas); lines of trees[1] (such as street trees); clusters of trees (e.g. as often found in parkland); and woodlands[2] (which may be located within or immediately adjacent to the urban footprint) – as well as both publicly and privately owned trees. Urban forest studies in the UK have shown that the proportion of city trees under private ownership ranges from approximately 25-75% (Doick and Davies, 2016); however, to narrow the focus for this thesis, only those trees in public ownership are considered here. The practice of ‘urban forestry’ is defined as "the management of trees for their present and potential contribution to the physiological, sociological and economic well-being of urban society. These contributions include the overall ameliorating effect of trees on their environment, as well as their recreational and general amenity value" (Jorgensen, 1986: 178). There is a clear focus in this definition on the need to manage urban trees for the benefits that they provide to people.

Ecosystem services (hereafter ES) are most commonly defined as "the benefits people obtain from ecosystems" (MEA, 2005: v), and are categorised into provisioning services (such as provision of food and timber), regulating services (such as air purification, heat amelioration and stormwater attenuation), and cultural services (such as aesthetic beauty and opportunities for recreation).[3] Whilst ES are provided by both rural and urban ecosystems, some are particularly relevant to the latter. Literature reviews by Gómez-Baggethun and Barton (2013) and Haase *et al.* (2014) found regulating and cultural services to be most important for resilience and quality of life in cities; particularly air purification, temperature regulation, health and wellbeing, stormwater regulation, noise mitigation, education and learning, carbon sequestration, and habitats for wildlife.

[1] A tree is a woody perennial plant, with a tall single stem (trunk) bearing lateral branches at some distance from the ground; this contrasts with a shrub which has multiple woody stems arising at ground level forming a crown at a lower height (Davies *et al.*, 2017a).

[2] A woodland is defined as an area with a canopy cover of at least 20%, a minimum area of 0.5 ha and a minimum width of 20 m (Forestry Commission, 2011).

[3] The Millennium Ecosystem Assessment (MEA, 2005) and the UK National Ecosystem Assessment (UK NEA, 2014) additionally included supporting services (such as nutrient cycling and primary production) as a category of ES. These were described as 'intermediate' services, underpinning the 'final' services of provisioning, regulating and cultural (Fisher *et al.*, 2011). However, the recent Common International Classification for Ecosystem Services (CICES) avoids the terms ‘intermediate services’ and ‘supporting services’, as these are processes and functions rather than services (Potschin-Young *et al.*, 2017; Haines-Young and Potschin, 2018).

Ecosystems can also have adverse effects on society – these 'disservices' are defined as "functions of ecosystems that are perceived as negative for human well-being" (Lyytimäki and Sipilä, 2009: 311). The urban forest is considered to be one of the main suppliers of ES – and disservices – in urban areas (Roy *et al.*, 2012; Dobbs *et al.*, 2014; Davies *et al.*, 2017a). To better account for the different ways in which people perceive the benefits and disservices provided by nature, Pascual *et al.* (2017) has proposed replacing the term ES with 'nature's contributions to people'. This is defined as "all the positive contributions, or benefits, and occasionally negative contributions, losses or detriments, that people obtain from nature" (Pascual *et al.*, 2017: 9).

Green infrastructure is defined by the European Commission (2013) (p.3) as "a strategically planned network of natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings". Green infrastructure includes features such as greenspace, rivers and trees, and has a crucial role to play in helping urban areas adapt to climate change through the provision of regulating ES (Foresight Land Use Futures Project, 2010). For example, trees in particular can alleviate summer heat through evapotranspiration, reflectance of radiation, and shading (Doick and Hutchings, 2013); reduce stormwater run-off by intercepting and absorbing water and improving infiltration (Armson *et al.*, 2013); and improve air quality by intercepting and/or absorbing gaseous pollutants and particulate matter (Escobedo and Nowak, 2009).

Finally, nature-based solutions are defined as "actions which are inspired by, supported by or copied from nature" that "aim to help societies address a variety of environmental, social and economic challenges in sustainable ways" (European Commission, 2015: 5). These are relevant to both urban and rural areas in developed and developing countries, and can address wider societal issues than addressed in this thesis, such as food security, water security, and disaster risk reduction. For the purpose of this thesis, which focuses on climate change adaptation and human wellbeing in the cities of temperate, developed countries, a narrower definition of nature-based solutions is therefore applied, encompassing "provision of urban green such as parks and street trees that may ameliorate high temperature in cities or regulate air and water flow" (Kabisch *et al.*, 2017: 2). As such, the strategically planned provision of regulating ES by urban forests (as a key component of broader green infrastructure) to address urban problems of surface water flooding, heat islands, and air pollution, is the nature-based solution addressed through this thesis.

1.1.3 Mainstreaming of nature-based solutions in urban planning

The use of nature-based solutions such as trees and other green infrastructure to tackle urban environmental problems represents a paradigm shift in the approach to urban planning. This 'ES-based approach' is defined by Martin-Ortega *et al.* (2015) (p.8) as a way of "understanding the complex relationships between nature and humans to support decision-making with the aim of reversing the declining status of ecosystems and ensuring the sustainable use/management/ conservation of resources". Core elements of such an approach include effects on human wellbeing; the biophysical underpinning of ES delivery; transdisciplinarity; and the assessment of ES for decision making (Martin-Ortega *et al.*, 2015).[4]

But is this happening? The academic literature suggests the extent to which ES are being considered in planning policy and decision-making remains inconsistent both across and within countries, and has rarely been researched outside of Europe. For example, a review of European policy documents by Lafortezza *et al.* (2013) led the authors to suggest that ES knowledge amongst policy makers and practitioners is low. Later, Geneletti and Zardo (2016) found that whilst the majority of European climate adaptation plans contain references to maintaining or enhancing green infrastructure for heat reduction and flood retention purposes, these lack sufficient detail for implementation. In contrast, recent urban planning documents in Italy frequently detail actions to increase provision of regulating urban ES (Cortinovis and Geneletti, 2018). One of the few North American studies published on the subject suggests that ES knowledge is fairly well implemented in Canadian municipal planning policy, with the ES concept often used to help deal with emerging urban challenges (Thompson *et al.*, 2019).

Research worldwide reveals a number of socio-political constraints are hindering the mainstreaming of ES into government decision-making. Firstly, a failure to present ES research in ways that are salient, credible, legitimate or at scales useful for decision makers (Turner and Daily, 2008; Wright *et al.*, 2017). Secondly, poor governance structures and limited public and business involvement (Guerry *et al.*, 2015; Ojea, 2015). Thirdly, the long-term nature of nature-based solutions mismatching with short-term political agendas (Faehnle *et al.*, 2015; Scott *et al.*, 2017). And fourthly, habitual modes of practice restricting forward-thinking decision-making (Naumann *et al.*, 2011; Hansen and Pauleit, 2014).

[4] Similarly, an 'ecosystem approach' has been defined by the UK government as providing "a framework for looking at whole ecosystems in decision-making, and for valuing the ecosystem services they provide, to ensure that society can maintain a healthy and resilient natural environment now and for future generations" (Defra, 2014a: online).

The academic literature also poses a number of potential approaches for mainstreaming ES and nature-based solutions in urban planning. For example, valuing them in monetary terms to increase their importance in the eyes of policy makers (Vandermeulen *et al.*, 2011); accessing funds from developers and businesses (Hansen *et al.*, 2016); and incorporating public values and preferences to gain support from local citizens (Ordóñez Barona, 2015). Furthermore, though the uncertainty surrounding the provision of ES is often seen as a barrier to action for local governments (Foster *et al.*, 2011), a number of studies suggest that this uncertainty simply needs to be considered and reported (Glenk *et al.*, 2014; Moffat, 2016). The notions of valuation, funding, values, and uncertainty in relation to environmental decision-making are discussed further in the following sub-sections.

1.1.4 Valuation as an approach for supporting decision-making

Within local authorities, green infrastructure is often seen as a liability – ignoring the wider social benefits to society – because in most cases, only the costs of greenspace management and tree planting and maintenance feature on local authority balance sheets (Scott *et al.*, 2017). However, by quantifying and monetising the human health, climate adaptation, and biodiversity benefits that the greenspaces and trees provide, this would enable a cost-benefit analysis to be carried out. If net benefits are positive, the green infrastructure will be seen as an asset rather than a liability, and it could even provide an argument in favour of increasing investment to enhance this asset (Scott *et al.*, 2017). Indeed, it has been argued in both the scientific and grey literature that putting a monetary value on green infrastructure assets and investments is necessary to convince politicians, citizens and other stakeholders of their usefulness (Vandermeulen *et al.*, 2011; Natural Capital Committee, 2015; Sunderland *et al.*, 2015).

For example, a study of US and UK citizens by Rode *et al.* (2017) found that cost-benefit analysis (where monetised ES benefits outweighed the costs) had as large an impact on their support for environmental protection measures as did a moral-ecological argument. Both of these arguments garnered significantly higher levels of support than a qualitative, anthropocentric ES argument (Rode *et al.*, 2017). The monetary argument appealed in particular to males, older participants and politically right-wing participants, suggesting that the approach could be useful for influencing those typically in positions of power. There are a number of different decision contexts in which the valuation of ES can inform urban planning. In order of increasing requirements for accuracy, these include: awareness raising, inclusion on local authority balance sheets, setting of policy priorities, design of funding mechanisms, and to compensate damage caused (e.g. the removal of trees by developers) (Gómez-Baggethun and Barton, 2013).

Numerous valuation tools have been developed to assist environmental decision-making – one of the most commonly used in urban environments is 'i-Tree Eco' (Raum *et al.*, 2019). A software application developed in the United States, i-Tree Eco models biophysical data about a sample of trees (collected in the field) along with hourly air pollution and meteorological data, in order to quantify and place a monetary value on the regulating ES they provide (USDA Forest Service, no date-b). Since 2002 there has been a proliferation in the use of i-Tree Eco in North America, Europe, and elsewhere, enabling the calculation of cost-benefit ratios as high as 1:6 for street trees in New York and Indianapolis. Many US cities using the i-Tree Eco tool have found that monetising the value of their urban forest ES has "led to increased appreciation of trees and tangible program enhancements" (Soares *et al.*, 2011: 69). However, a systematic review conducted by Song *et al.* (2018) revealed cost-benefit analysis of urban forests has rarely been undertaken outside of North America. Nevertheless, i-Tree Eco studies have resulted in improvements to urban forest budgets, policies and management in several UK local authorities (Hall *et al.*, 2018).

However, there are also drawbacks to using monetary valuation of ES in the decision-making process, and this approach continues to be contested in the academic literature. For example, Salles (2011) and Spangenberg and Settele (2010) lament both the inconsistency and subjectivity of valuation results, and the fact that the few ES that are regularly monetised end up being prioritised over ES which are harder to put a value on. Others point to the inability of monetary valuation to capture the diversity of values ecosystems have, both in their own right, and for different groups of people (Bunse *et al.*, 2015; Jacobs *et al.*, 2016). Furthermore, the heterogeneity present within urban areas – along with the sheer density of people and infrastructure – poses additional challenges to valuation (Gómez-Baggethun and Barton, 2013). For example, there will be greater socio-economic and cultural diversity; multiple environmental stressors; more substitution possibilities between natural and man-made features; varying levels of connectivity between people and green infrastructure; an ever changing urban fabric; and an over-emphasis on more localised disservices (Gómez-Baggethun and Barton, 2013). Due to the limitations of valuation methods (some of which are discussed further in sub-sections 1.1.6 and 1.1.7 below), Tinch *et al.* (2019) suggest that monetary valuation of ES is best used for aiding reflection and deliberation processes, rather than as the foundation of decision-making.

1.1.5 Alternative funding of environmental enhancement

Despite the benefits that green infrastructure provides to society, for reasons mentioned in the preceding sub-sections, it has long suffered from low levels of funding and support from local governments (Pauleit *et al.*, 2002; van der Jagt and Lawrence, 2019). In the absence of sufficient

resources within local authorities, it may be necessary to seek additional funding from the beneficiaries of ES, i.e. communities and the private sector (Rowcroft *et al.*, 2011).

Iftekhar *et al.* (2017) suggest that by being "largely immune to the short-term political cycles and public pressures on competing policy priorities, corporate sponsors may provide a secure and flexible source of restoration funding" (p.266). There are examples of private investors and individuals making substantial contributions to environmental management and conservation programs – particularly in the United States. New York's Central Park Conservancy meets a large proportion of its budget requirement through philanthropic donations (Mell, 2016a), whilst almost a quarter of the $150,000 spent by the River Network (a US-based association) on restoration projects in 2011 was sourced from corporate funders (BenDor *et al.*, 2015). In the UK, external funding of green infrastructure includes business sponsorship; contributions from developers as a condition of planning consent; and transferring management of publicly-owned greenspace assets to community groups eligible for grant funding – however these are typically small and ad hoc (Mell, 2016b).

There are also incentive-based policy or market instruments that are used to enable those who provide ES to be paid by those who benefit from them, thus increasing the quality and quantity of ES provision. 'Payments for ecosystem services' (PES) is defined as "a transfer of resources between social actors, which aims to create incentives to align individual and/or collective land use decisions with the social interest in the management of natural resources" (Muradian *et al.*, 2010: 1205). Since the early 1990s, hundreds of PES schemes have been implemented in developed and developing countries throughout the world – usually involving restoration of watersheds and forests (Grima *et al.*, 2016). PES schemes are funded through a range of public and private sector sources, including mandatory contributions from citizens (via an increase in government taxes) and consumers (e.g. through an increase in water rates). Organisations also contribute voluntarily where there is a clear link to the success of their business – typically either those dependent on ES provision (e.g. water resources, biodiversity or amenity benefits) or those wishing to improve their image and/or mitigate their impacts (e.g. through carbon sequestration) (Koellner *et al.*, 2010; Meißner, 2013).

Despite numerous success stories, PES schemes are not without their drawbacks and critics. For example, Chan *et al.* (2017) identify seven key concerns: misplacement of rights and responsibilities; top-down prescription/alienating agency; new externalities; crowding out existing motivations; efficiency-equity tradeoffs; limited applicability; and monitoring costs (leading to assumed rather than proven benefits). The latter point is explored more in sub-section 1.1.7, whilst the first concern relates to fairness. It could be argued that provision of urban forest ES is

the sole responsibility of local authorities (who receive income through council tax and business rates) – is it fair for beneficiaries (as opposed to polluters) to have to pay again through a PES scheme? Or if paying voluntarily, will this not give undue influence over urban forest planning and management to the wealthy, to the detriment of marginalised groups, or those residing in more deprived areas (McDermott *et al.*, 2013; Pascual *et al.*, 2014)?

There also remains a gap in knowledge as to the feasibility of such schemes in exclusively urban areas, or when more than one ES is to be funded (as will usually be the case in urban areas) (Grima *et al.*, 2016; Ola *et al.*, 2019). Several authors have suggested that urban PES schemes are likely to be more challenging to establish because of the large number of fragmented beneficiaries and less obvious link between land use/management and ES delivery resulting in higher transaction and implementation costs and more free riding (Wertz-Kanounnikoff *et al.*, 2011; MacGillivray and Wragg, 2013; Eves *et al.*, 2015). During 2012-2015, the UK Government funded 16 PES pilot projects in order to test the suitability of PES in new contexts, with three being located in urban areas (Defra, 2016a). In two of the urban pilots, private businesses and citizens expressed interest in paying for green infrastructure enhancements to improve amenity, recreation, biodiversity, water quality and flood regulation services, however, the third found no interest from potential business-only buyers due to 'inadequate incentives' (Defra, 2016a). Whilst establishing urban green infrastructure partnerships amongst multiple stakeholders with different viewpoints can be complex (Roe and Mell, 2013), the two 'successful' urban PES pilots may have benefited from inclusion of a wide stakeholder base. One of these has since led to the development of an innovative Catchment Partnership, involving two major local businesses (Defra, 2016a).

In practice, an effective and large-scale means of increasing business (and citizen) contributions to urban green infrastructure and the ES it provides is yet to be established. A potential way of increasing support and funding for urban ES delivery over the long-term is to create innovative partnerships between local authorities, citizens and businesses – potentially based on the PES model (Defra, 2016a; Hansen *et al.*, 2016; Iftekhar *et al.*, 2017).

1.1.6 Importance of stakeholder values and preferences

'Value' is defined as "how useful or important something is", whilst 'values' are "the beliefs people have, especially about what is right and wrong and what is most important in life, that control their behaviour" (Cambridge Dictionary, 2019). However, there is increasing debate about values in relation to socio-ecological systems, and a number of different value frameworks have been devised (Jacobs *et al.*, 2018). For example, the 'Total Economic Value' framework describes

five different value types: direct use values (e.g. provisioning services); indirect use values (e.g. the regulation of air pollution); option values (e.g. preservation of forests for future use); bequest values (non-use, relating to preservation for future generations); and existence values (non-use, relating to the satisfaction people gain from knowing that nature exists). Drawing on this, the UK National Ecosystem Assessment (NEA) includes individual wellbeing values from ES that can be consumed directly, and collective/shared wellbeing values from indirect or non-use of ES (Mace *et al.*, 2011). Another framework is 'The Economics of Ecosystems and Biodiversity', which considers three domains of value: ecological values (i.e. nature's capacity to provide ES); sociocultural values (contributions of nature towards cultural identity and wellbeing); and monetary values (contributions of nature to individual welfare) (TEEB, 2010).

The values referred to above are all forms of instrumental value, i.e. the value of nature to people. Due to the anthropocentric nature of the ES concept, intrinsic values (the value of nature for its own sake) are not generally considered. However, many people consider that trees and other aspects of the natural environment have the right to exist irrespective of human benefit (Pearce, 2001; Piccolo, 2017). Furthermore, in recent years a number of studies (Chan *et al.*, 2016; Pascual *et al.*, 2017; Chan *et al.*, 2018) have proposed a widening view of values to include preferences, principles and virtues about socio-environmental relationships, known as relational values. These are values 'about nature' and 'of nature', encompassing what people find meaningful about nature (e.g. attachments and responsibilities), as well as the contribution of nature towards human wellbeing (e.g. by connecting people to the land, or motivating a nature-based recreational activity) (Chan *et al.*, 2018). The most recent, and increasingly popular, value framework – that of The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) – encompasses these broader views of value. IPBES (2015) sets out three value dimensions: non-anthropocentric values (i.e. the intrinsic and inherent values of nature); instrumental values (the contributions of nature to people); and relational values (addressing the relationships between people and nature).

Not only do different people hold different values and value dimensions for nature, but individuals may also attach multiple different meanings and viewpoints to nature at the same time (Hubacek and Kronenberg, 2013; Sander and Zhao, 2015). Given the size and heterogeneity of urban areas, held values may be numerous and vary widely across the population. As pointed out by Jacobs *et al.* (2018), the majority of valuation methods which target only a single type of value can represent just a small part of society's beliefs and preferences. Jacobs *et al.* (2018) add that no existing valuation method is able to capture the full spectrum of nature's values, and so use of a combination of appropriate monetary, biophysical, socio-cultural and synthesising methods is recommended.

Biophysical valuation methods are used to identify the capacity of different green infrastructure features to provide ES, and can thus guide local tree planting and maintenance decisions (e.g. see Davies *et al.*, 2017a). Whilst biophysical valuation may help to show the importance of green infrastructure (e.g. compared to grey infrastructure), as alluded to in sub-section 1.1.4, it is unlikely to impact on funding decisions to the same extent as monetary valuation. Socio-cultural valuation meanwhile aims to identify nature's contributions to human wellbeing, and in particular which ES are most preferred – by whom and why (Martín-López *et al.*, 2014). The relative importance that citizens place on the different ES provided by green infrastructure is well researched in the worldwide academic literature. For example, the studies ascertaining preferences for urban forest ES reviewed in sub-section 2.3.1 of this thesis reveal the top five ES to be, in order: aesthetic beauty, heat amelioration, air purification, habitat for wildlife, and recreation opportunities. Whilst socio-cultural valuation may influence decision-makers in terms of which ES they prioritise, again it is unlikely to increase levels of funding like monetary valuation can.

One monetary valuation method with particular relevance to (external) funding of environmental enhancements is the stated preference method, whereby respondents reveal (either directly or indirectly) their willingness-to-pay (WTP) for the protection or enhancement of particular environmental goods or services. The method assumes that stated WTP amounts are based on respondents' underlying preferences for the environmental goods or services (Hanley *et al.*, 2001). As long as the sample is sufficiently large and representative of the population, these monetary values represent the level of human wellbeing that society derives from the proposed environmental enhancement (Bateman *et al.*, 2002).[5] Whilst the stated preference method is typically used to show the monetary value people assign to a proposed environmental enhancement, it can also be used to determine the amount of money that citizens may be willing to contribute to that enhancement, e.g. through taxes or user fees. However, the method has rarely been used to indicate people's WTP for one ES over another, which is surprising considering that most PES schemes are focused on provision of a single ES. The different types, domains and dimensions of values people hold play a significant role in explaining their behaviour (de Groot and Steg, 2008). Consequently, values have strong implications for the viability of a citizen-funded PES scheme – especially one operating in an urban area (Muradian *et al.*, 2010; Chan *et al.*, 2018).

[5] Note that there are a number of studies critiquing these assumptions, due to the hypothetical, often complex nature of the method. The limitations of stated preference WTP studies are discussed in sub-sections 5.4.4 and 6.6 of this thesis.

1.1.7 Uncertainty in provision of ecosystem services

Socio-ecological systems such as urban forests involve highly complex and heterogeneous interactions within and between processes and actors at different scales (Janssen and Ostrom, 2006; Steenberg, 2018). This results in an indefinite or unquantifiable likelihood of future events – defined by Knight (1921) as uncertainty; whilst what those future events are may also be unknown. Mehta *et al.* (2001) identified four different types of uncertainty relevant to people's use of natural resources: ecological, livelihood, knowledge, and social and political uncertainties.

The first, ecological uncertainty, relates to the variability in ecosystem processes. A key issue with the use of nature-based solutions to city problems is that due to the complexity of socio-ecological systems, there can be unanticipated responses to changes in land management (Ainscough *et al.*, 2018). For example, the provision of ES from urban trees depends greatly on the size, structure, and species of the trees; their proximity to people, buildings and/or sources of environmental harm; and the level of management/pruning (Davies *et al.*, 2017a). Management activities also tend to focus on only one ES at a time, which can lead to unanticipated trade-offs between services and thus a reduction in expected benefits (Bennett *et al.*, 2009; Mouchet *et al.*, 2014; Salmond *et al.*, 2016). The second type of uncertainty, livelihood, relates to the different ways in which sudden changes in environmental (or economic) conditions can affect peoples' wellbeing (Mehta *et al.*, 2001). In an urban forest context, this could be external, stochastic factors such as weather and climate. Unpredictable conditions such as air temperature, precipitation, relative humidity, and wind speed can affect the ability of an urban forest to provide ES, or result in the production of disservices (Roy *et al.*, 2012).

The third type of uncertainty, knowledge, is attributable to the fact that scientific perspectives are "plural, partial, contingent, situated and contested" (Mehta *et al.*, 2001: 2). In other words, ES studies are spatially and temporally specific, with different tools making use of different underlying data, and models being underpinned by a range of assumptions (Barnaud and Antona, 2014; Costanza *et al.*, 2017). Not only are ES are quantified and monetised in many different ways, but few of the tools used explicitly acknowledge uncertainty (Hamel and Bryant, 2017; Ashley *et al.*, 2018). Furthermore, the multiple values that different people attach to nature (as discussed in the preceding sub-section) is another facet to knowledge uncertainty (Mehta *et al.*, 2001). The fourth type of uncertainty, social and political, relates to differences and changes in local socio-political structures. In an urban forest context, the affluence and population density of the local community can affect the perceived and actual provision of ES, as can local political priorities (Dobbs *et al.*, 2014). As a result, there can also be unanticipated human responses to

both proposed and actual changes in land management – again, particularly in urban areas (Mouchet *et al.*, 2014).

A further type of uncertainty, likely a culmination of the four types of uncertainty discussed by Mehta *et al.* (2001), is that of decision uncertainty. This can affect people's ability to make decisions with regards to unfamiliar ES (Dekker *et al.*, 2016). This is a particular problem for those with responsibility for urban planning and policy making, with uncertainty over outcomes often seen as a barrier to action for local governments (Foster *et al.*, 2011). In other cases, uncertainty in ES delivery is simply ignored. For example, due to the complexity and cost of measuring scheme outputs, the majority of the world's PES schemes are based on assumptions and good faith rather than actual evidence of ES delivery (Kroeger, 2013; Hejnowicz *et al.*, 2014). However, van de Sand (2012) suggests that payments based on false perceptions of critical links between land use and ES delivery could be detrimental to the environment/society in the long run. Furthermore, as citizens receive fewer benefits than expected, they are likely to doubt or mistrust – and thus reduce support for – future programmes (Moffat, 2016; Lima *et al.*, 2017).

To improve the feasibility, effectiveness, and credibility of environmental programmes, it has been suggested that outcome uncertainty be considered in decision-making (Vandermeulen *et al.*, 2011; Glenk *et al.*, 2014). A small number of stated preference studies look at WTP for (mainly rural) environmental schemes with outcomes presented as uncertain, finding respondents willing to pay less (and less willing to pay) than for certain outcomes (Wielgus *et al.*, 2009; Rolfe and Windle, 2010). However, there is a lack of research investigating people's *perceptions* about the supposed benefits of a programme, as it is possible that acknowledging outcome uncertainty could enhance rather than reduce interest in PES schemes (Burghart *et al.*, 2007; Lundhede *et al.*, 2015). Either way, uncertainty also has strong implications for the viability of a citizen-funded, urban PES scheme.

1.2 Research problem addressed and approach taken

As highlighted in the above sections, the use of green infrastructure as a nature-based solution to urban problems remains limited by the silo, short-term, habitual and reactive approach to urban planning worldwide. This thesis posits that a proactive, partnership approach that brings in additional funding and support for green infrastructure from businesses and citizens could be key to addressing this issue. However, this solution rests on academic knowledge regarding the notions of valuation, funding, values, and uncertainty in relation to environmental decision-making; for which there are gaps – particularly for urban settings. For example, does putting a monetary value on individual urban ES make sense, and does it help to raise the importance of

urban green infrastructure in the minds of decision-makers and potential funders? How would a beneficiary-pays model account for diversity in values and socio-ecological uncertainties, and is an urban setting simply too complex for such a scheme to work? In order to focus the research, the problem that this thesis seeks to address is investigated in the context of UK urban forestry, for the reasons described below.

1.2.1 Case study application: UK urban forestry

The UK has one of the highest proportions of people living in towns and cities in the world; rising since the early 1990s the national urban population reached 83% of all UK residents in 2017, up from 78% in 1997 (Champion, 2014; The World Bank, 2018). To accommodate this rising urban population, urban densification policies have resulted in the loss of both greenfield and brownfield sites (Drayson and Newey, 2013). Meanwhile, the UK government's Climate Change Risk Assessment reveals the greatest climate change threats to the country to be flood and heat-related risks to communities and businesses (Committee on Climate Change, 2017). Figures from the Met Office (2018) reveal the twelve warmest years on record in the UK, and five of the seven wettest years, have all occurred since 2002; and these trends are set to continue. Air quality is also a growing problem in UK cities. London is not expected to be compliant with EU air quality regulations (such as Directive 2008/50/EC on Ambient Air Quality and Cleaner Air for Europe) until at least 2025 (Cuff, 2016). Five other English cities (Birmingham, Leeds, Nottingham, Derby, and Southampton) which continue to exceed the annual mean standard for nitrogen dioxide (NO_2) are required to introduce 'Clean Air Zones' by 2020 (Defra, 2015a).

England's Forestry Strategy (Defra, 2007) specifically promotes the use of trees and woodlands to help minimise the impacts of climate change in built-up areas. However, Davies *et al.* (2011) revealed that though recognition of regulating ES has generated renewed interest in urban tree planting, the adoption of such schemes in the UK has been patchy and uncoordinated. Furthermore, anecdotal evidence suggests that urban tree canopy cover in England is decreasing rather than increasing (e.g. Britt and Johnston, 2008; Urban FWAC Network, 2015; Moffat, 2016).[6] Unfortunately, limited political and public support in the UK has meant investment in the urban forest and other green infrastructure has been lacking for some time (Britt and Johnston, 2008; Rowcroft *et al.*, 2011; Moffat, 2016). This has not been helped by the period of austerity launched by the UK coalition government in 2010, which reduced local council spending on environmental planning initiatives by 48.6% over the period to 2015 (National Audit Office, 2014; Innes and

[6] This trend is not confined to the UK; the United States has lost an estimated 36 million urban trees per year over the period 2009-2014 (Nowak and Greenfield, 2018).

Tetlow, 2015). Coupled with this, trees in UK cities are often seen not as an asset or provider of benefits, but as a liability – posing a risk to people and property (Van der Jagt and Lawrence, 2015). To some extent, the lack of funding and support undermine each other in a downward spiral, as reduced maintenance results in more complaints about trees causing nuisances, which reduces support, and thus funding, even further. Moffat (2016) suggests the failure of UK tree officers to adequately communicate the benefits of trees to politicians and the public is also partly to blame.

Sub-section 1.1.4 highlighted the importance of placing a monetary value on natural assets such as trees if they are to be taken seriously in decision-making. Explicit cost-benefit analysis for urban forests appears to be absent in Britain; nevertheless, the benefits highlighted through the 2010 i-Tree Eco survey of Torbay resulted in the council adding an additional £25,000 to its tree planting budget in 2011, and again in 2014 (Doick *et al.*, 2016a). Tree budgets in several other British local authorities have also been increased or protected following i-Tree Eco studies, though improved awareness of ES amongst decision-makers has been a more typical outcome (Hall *et al.*, 2018; Raum *et al.*, 2019). Recently, the UK Government's 25 Year Environment Plan has stated an ambition to plant one million urban trees by 2022, though as only £10 million has been made available for this, additional contributions are also required from cash-strapped local authorities and/or external sources (Defra, 2018a; HM Treasury, 2018). As with other countries, external funding of urban forests is limited in the UK. Whilst 'Friends of' groups and other voluntary community-based organisations have access to grant opportunities and provide support to Britain's urban forests in terms of labour and collective decision-making, such groups rarely provide much in the way of funding (Swade *et al.*, 2013). Business and citizen sponsorship of trees and green spaces in the UK is also minimal (Mell, 2016a) – though this may signify a lack of opportunity rather than a lack of appreciation for the urban forest amongst these groups.

Despite the use of a case study centred on provision of regulating ES from UK urban forests, this thesis nevertheless has relevance to the provision of a range of urban ES from green infrastructure throughout Europe, and potentially elsewhere in the developed, temperate world.

1.2.2 Conceptual framing of the research problem

There has been much debate in the literature as to whether 'services', 'benefits' and 'values' are different concepts or one-and-the-same (e.g. MEA, 2005; Mace *et al.*, 2011; Potschin and Haines-Young, 2011; Ojea *et al.*, 2012; Spangenberg *et al.*, 2014; Costanza *et al.*, 2017; Hausknost *et al.*, 2017; Ordóñez *et al.*, 2017). This thesis does not intend to enter this debate, but uses the terms that are most appropriate for the particular aspects of the research problem being addressed.

Typically, the terms 'ES' and 'benefits' are used interchangeably, with 'values' considered separately. Further, values are usually discussed in the instrumental sense, given the association with payments; but relational values (in the context of moral duty) are also relevant.

Whether services, benefits and values (along with ecosystem functions and external drivers of change) should be depicted as a circular model, a 'cascade', a 'stairway', or a more complex socio-ecological system has also been debated extensively in the literature (e.g. TEEB, 2010; Mace *et al.*, 2011; Potschin and Haines-Young, 2011; Fisher *et al.*, 2013; Spangenberg *et al.*, 2014; Díaz *et al.*, 2015; Costanza *et al.*, 2017; Hausknost *et al.*, 2017). This thesis does not seek to support one ES conceptual framework over another, nor to propose a new one. Instead, it takes elements of the frameworks of TEEB (2010), the UK NEA (Mace *et al.*, 2011), Potschin and Haines-Young (2011), Spangenberg *et al.* (2014), and Hausknost *et al.* (2017), and adapts them to suit the specific research problem being addressed. This adapted framework – focused on the external funding and enhancement of publicly provided, uncertain, urban forest ES – is shown in Figure 1.1.

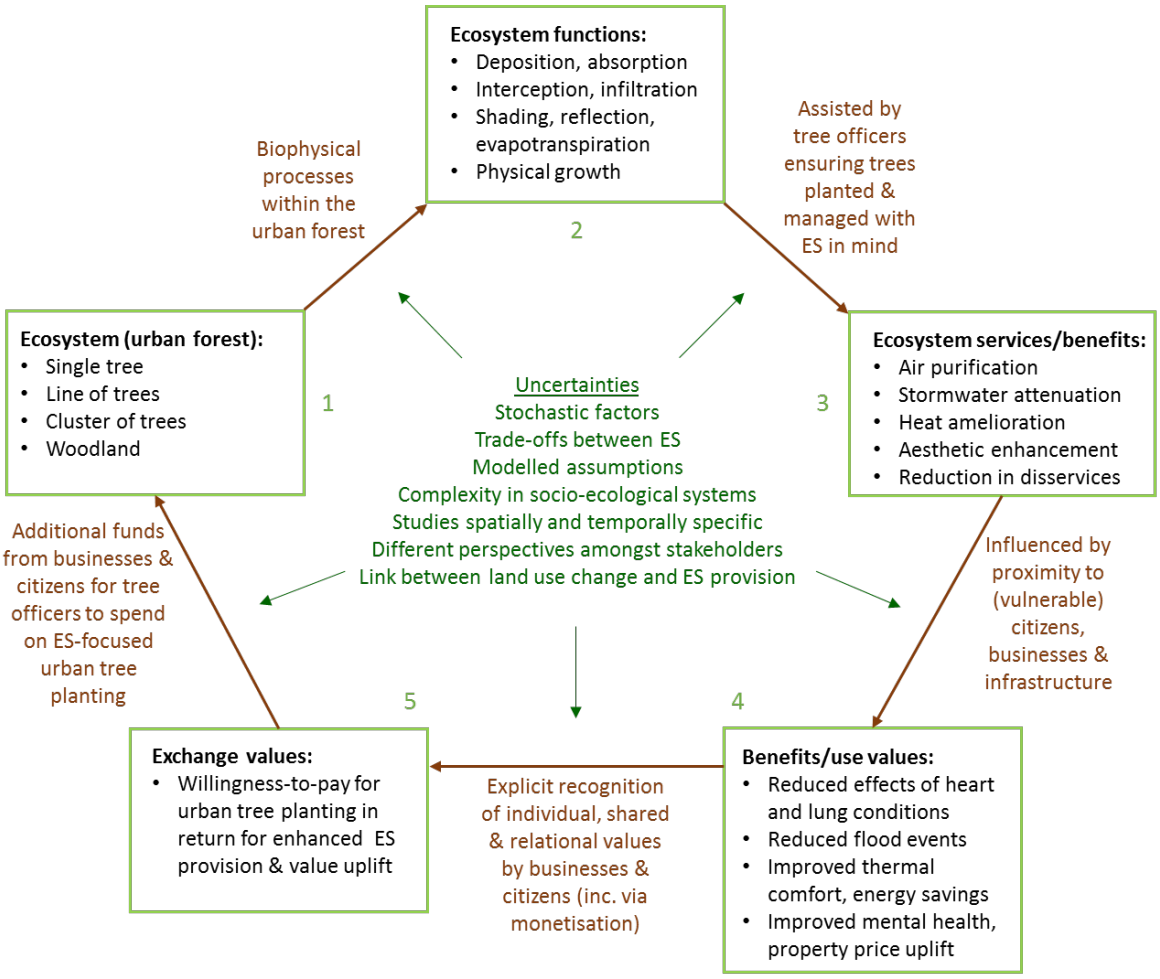


Figure 1.1: Conceptual framework for an urban forest payments for ecosystem services scheme with uncertain outcomes (adapted from TEEB, 2010; Mace et al., 2011; Potschin and Haines-Young, 2011; Spangenberg et al., 2014; Hausknost et al., 2017)

This framework starts with the ecosystem in question (an urban forest), and shows how, through biophysical processes, different ecosystem functions occur (dependent on biophysical and stochastic factors). If these trees are located in the right places and managed appropriately, then these functions will translate into ES of benefit to people (although there may be trade-offs between ES). The extent to which individual citizens and businesses value these benefits will depend on their proximity to and use of the ecosystem, as well as their varied and multiple perceptions of ES provision. Explicit recognition of these values, perhaps facilitated by qualitative, quantitative or monetary studies, or other awareness raising techniques, can lead to a willingness to make direct financial contributions (e.g. through a PES scheme) towards ES-focused tree planting. This enhances the original ecosystem, with positive implications for each of the subsequent steps. The framework is therefore circular – in fact representing an upward spiral – with external factors and uncertainties present at every step.[7]

1.2.3 Thesis objectives

The overarching aim of the thesis is to establish whether a public-private urban forest PES scheme could be a feasible approach for addressing the constraints to delivery of ES in cities, thus improving climate change adaptation and quality of life. To help achieve this, the research is broken down into a number of objectives and research questions, as set out below. These are addressed in the context of the UK, with the results of Objective 1 informing Objectives 2 and 3 (for which the city of Southampton is used as a case study).

Objective 1

Establish the extent to which local authorities manage their urban forests for regulating ES provision, and the drivers for, and constraints to, taking such an approach.

1. What are the main objectives for urban forest management?
2. Do local authorities manage their urban forests for regulating ES and, if so, why and how?
3. What are the constraints to adopting proactive, ES-focused urban forest management?
4. How might local authorities adopt an ES approach going forwards?

Objective 2

Establish how business attitudes towards urban ES affect the way that businesses might approach the financing of urban trees, e.g. through a PES scheme.

[7] Note that this thesis focuses mainly on the third step onwards; the initial steps of the framework are discussed in detail in Davies et al. (2017a), which was written during the PhD candidature.

1. What are business attitudes towards urban trees and the ES they provide?
2. What are business attitudes towards private sector investment in urban forests?
3. What are business preferences regarding the operation of an urban forest PES scheme?

Objective 3

Establish how the willingness-to-pay (WTP) of citizens for provision of urban forest ES is affected by public preferences and values, and the objective and subjective uncertainty surrounding urban ES delivery.

1. What are citizen attitudes towards urban ES, and how does this affect their WTP for a PES scheme that focuses on urban forest-based air purification, stormwater attenuation, and aesthetic enhancement?
2. To what extent is citizen WTP for air purification, stormwater attenuation and the PES scheme as a whole, affected by the objective uncertainty associated with delivery of these ES?
3. To what extent is citizen WTP for air purification, stormwater attenuation and the PES scheme as a whole, affected by the subjective uncertainty people associate with delivery of these ES?

1.2.4 Methods

The thesis takes a mixed-methods approach, combining qualitative research (e.g. telephone interviews and thematic analysis) with quantitative research (e.g. online surveys and choice modelling). A number of authors (e.g. Hattam *et al.*, 2015; Posner *et al.*, 2016; Juntti and Lundy, 2017; Lau *et al.*, 2019) have found mixed-methods research to bring greater depth and understanding to studies of ES than can be gained from the individual approaches alone – particularly where different types of stakeholder values are involved. Mixed-methods were considered to be the most effective way of addressing the research problem because of the variety of stakeholders involved (local authority tree officers, businesses, and citizens) and the different information required from each group. Why these specific stakeholders and methods were chosen is discussed below; additional detail on methods is provided in the three papers (see sections 3.2, 4.2 and 5.2).

Objective 1

Objective 1 involved conducting detailed, semi-structured interviews with local authority tree officers from 15 of the UK's most densely populated urban areas. Previous studies have used quantitative surveys to provide an insight into urban forest management by all local authorities in

England and Scotland (Britt and Johnston, 2008; Van der Jagt and Lawrence, 2015). However, given that an ES-approach to urban forest management has not previously been researched – and the fact the thesis is focused on cities only – it seemed that in-depth interviews (analysed qualitatively) with a sub-sample of tree officers would be most appropriate. In-depth interviews were also particularly appropriate for answering the research questions for Objective 1, as they enabled the reasons and meanings behind the tree officers' views and perceptions to be understood, which cannot be observed via a quantitative method collection.

Objective 2

Objective 2 involved conducting questionnaire-based interviews with business representatives from a single UK city, analysed both qualitatively and quantitatively. The city of Southampton was chosen for the interviews because it has:

- the second highest population density of any British local authority outside of London (Eurostat, 2016);
- continually failed to comply with EU law on limits for nitrogen dioxide (NO_2) (Defra, 2015a), and ranks in the top seven UK towns/cities for particulate matter pollution (World Health Organization, 2016);
- a high risk of surface water flooding and urban heat islands due to its urban nature and continued development, which are projected to worsen with climate change (Southampton City Council, 2014); and
- a proactive local authority that actively supports university research, and uses the Green Space Factor[8] in planning decisions in order to enhance ES provision from land use change (Farrugia *et al.*, 2013).

Interviews were used because there was no existing research on the willingness of businesses to invest in urban forest ES (making this an exploratory study), and it was important to understand underlying business attitudes to successfully answer the research questions. However, the interviews were questionnaire-based rather than in-depth in order to speed up the data collection process. This was partly because of the intention to sample a larger number of respondents for this Objective, aiming for representativeness of responses by covering a broad range of business sizes and sectors, thus enabling quantitative analysis. It was also partly to reduce the amount of

[8] The Green Space Factor is a planning policy tool that has been adopted by a number of city authorities across Europe to incorporate green infrastructure in development projects. The tool allocates a score to different types of surfaces based on infiltration potential, which is used as a proxy for ES delivery.

time each business would have to 'give up' by taking part in the study, as Koellner *et al.* (2010) and CLES and TWT (2015) both found some reluctance amongst businesses to engage in research.

Objective 3

Objective 3 involved conducting an online, questionnaire-based, discrete choice experiment with a sample of Southampton residents. The city of Southampton was used for the same reasons as outlined above. However, as citizens outnumber businesses, and especially local authorities, by a large margin, it was deemed appropriate to use quantitative methods on as large a sample as possible. The purpose of this Objective was to understand social values and preferences (which require extracting information from the public), and for this to be meaningful it has to be extracted from a representative sample of the population – again requiring large numbers. Because of the larger sample size for this Objective, an online questionnaire was used so as to speed up and reduce errors in data processing.

A key way to learn about people's preferences and willingness-to-pay (WTP) for non-market goods such as regulating ES is to ask people about them using stated preference techniques (Kanninen, 2006). A discrete choice experiment (DCE) was chosen over the alternative stated preference technique of contingent valuation, because, whilst the latter is suitable for ascertaining WTP for changes to urban forests as a whole, DCEs enable the individual valuation of specific aspects of an urban forest programme, such as the different ES it provides (Pearce *et al.*, 2002). DCEs are carried out by asking a large number of people hypothetical questions via a questionnaire, and then using choice modelling (and linear regression) to analyse the results.

1.3 Structure of this thesis

This thesis follows a three paper format. The three papers are preceded by this introduction and a chapter reviewing the relevant literature, and are followed by a chapter which reflects on the key findings in the context of the research problem, literature and policy. Figure 1.2 shows how the thesis is organised and where each of the three objectives are addressed. Further detail on the content of the six chapters is provided below.

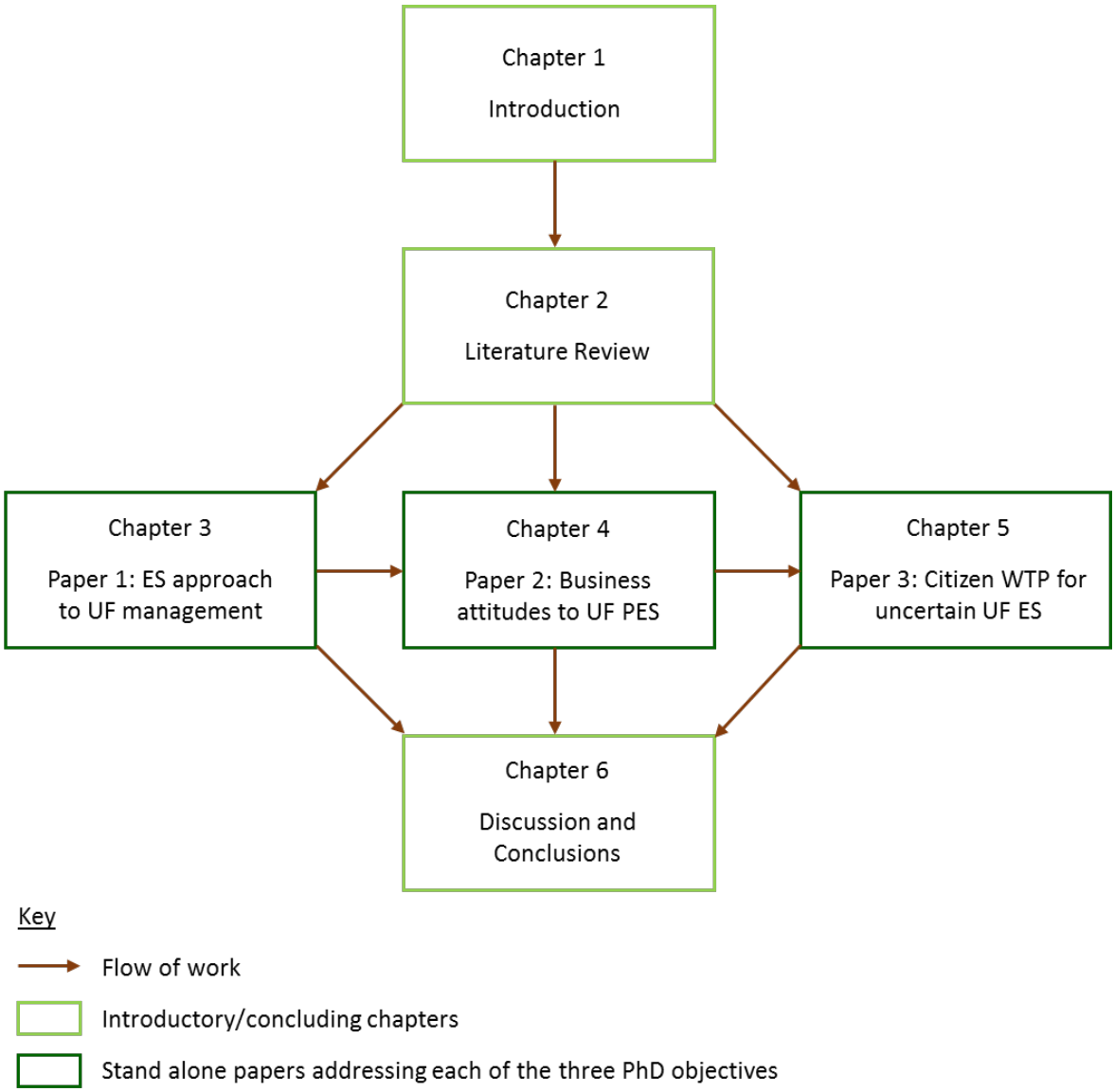


Figure 1.2: Thesis structure

Chapter 1 – Introduction

This chapter has introduced the concepts of urban forests and ES; detailed the research problem in terms of addressing the lack of funding and support for (uncertain) nature-based solutions to city problems; and set out the approach to this thesis, including the conceptual framework, the aim and objectives, and the methods used to address these.

Chapter 2 – Literature Review

This chapter provides context for the aim and three objectives of the thesis by reviewing literature from across the world, focusing in particular on Great Britain and other developed countries in temperate climates (particularly Europe and North America). As each of the three papers contain their own brief reviews of the literature, this chapter provides additional detail only on the points raised in the papers.

Chapter 3 – Paper 1: Challenges for tree officers to enhance the provision of regulating ES from urban forests

This is a slightly amended version (to improve thesis flow) of Davies *et al.* (2017b), which addresses Objective 1 of the thesis using the data obtained from the interviews with local authority tree officers. The results of this paper have informed the research undertaken for Objectives 2 and 3.

Chapter 4 – Paper 2: Business attitudes towards funding ES provided by urban forests

This is a slightly amended version of Davies *et al.* (2018), which addresses Objective 2 of the thesis using the data obtained from the interviews with business representatives in and around Southampton.

Chapter 5 – Paper 3: Citizen WTP for an urban forest PES scheme with uncertain outcomes

This addresses Objective 3 of the thesis using the data obtained from the choice experiment with citizens of Southampton.

Chapter 6 – Discussion and Conclusions

This chapter reiterates the purpose of the thesis in the context of the wider literature; and then reflects on the key findings from each of the three papers, and the common threads between them. The chapter then explains the potential implications of the thesis for government policy, on-the-ground partnerships and funding, and the direction of future academic research. Finally, the chapter highlights the limitations of the study overall, and makes recommendations for further research.

Chapter 2 Literature Review

Literature from across the world has been reviewed where relevant, however a greater focus has been placed on developed countries in temperate climates, as these are more relevant to the UK context. To support the aim and three objectives of the thesis, the three sections of this literature review address the following questions:

1. To what extent are ES considered in government decisions on urban planning, and how might this be improved?
2. What are business attitudes towards urban forest ES, and could ES provision be privately funded through a PES scheme?
3. What are citizen preferences regarding urban forest ES; how much are citizens willing to pay for their provision; and how does uncertainty over ES delivery affect this?

2.1 Objective 1: An ecosystem services approach to urban planning

The 'Ecosystem Approach' is a specific framework for action adopted by the Convention on Biological Diversity (2000) (p.1) as a "strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way". The UK government defines *an* 'ecosystem approach' as providing "a framework for looking at whole ecosystems in decision-making, and for valuing the ecosystem services they provide, to ensure that society can maintain a healthy and resilient natural environment now and for future generations" (Defra, 2014a: online). Meanwhile, Martin-Ortega *et al.* (2015) (p.8) define ES-based approaches as ways of "understanding the complex relationships between nature and humans to support decision-making with the aim of reversing the declining status of ecosystems and ensuring the sustainable use/management/conservation of resources". Core elements of such an approach include effects on human wellbeing; the biophysical underpinning of ES delivery; transdisciplinarity; and the assessment of ES for decision making (Martin-Ortega *et al.*, 2015). This part of the literature review attempts to find out to what extent ES are being considered in governmental decision-making – especially at local level – and in particular relating to urban forest planning and management. The section then identifies the main constraints to adopting an ES approach to urban planning, and possible solutions to such constraints, with examples from UK, European, North American and world-wide literature.

2.1.1 Consideration of ecosystem services in urban planning

Schubert *et al.* (2018) suggest that "planning has shifted over time toward a more holistic view of ES and their significance for human well-being and urban sustainability" (p.298), and that there has been a gradual transition from implicit to more explicit use of ES terminology. However, the academic literature suggests the extent to which ES are being considered in planning policy and decision-making remains inconsistent both across and within countries, and furthermore, that this has been a common topic of research in Europe, but seemingly not elsewhere.

In Europe, a review of policy documents against a 'green infrastructure framework' at different spatial scales by Lafortezza *et al.* (2013) revealed few connections being made between green infrastructure and ES at urban or city-region scale. This led the authors to suggest that ES knowledge amongst policy makers and practitioners overall remains low. At the same time, Hauck *et al.* (2013) reported that decision-makers are beginning to integrate ES into policy-making processes in Europe, citing the example of the EU Biodiversity Strategy (European Commission, 2011) that links ES to tangible aims. However, strategic policy at the level of a continent has little connection to the decisions made by those managing ecosystems on the ground. Indeed, the only example given by Hauck *et al.* (2013) of the EU Biodiversity Strategy being implemented was by researchers in Germany, regarding the development of a set of ES indicators for mapping ES at national level. Though useful, it is not clear how this supply-side information would be used to improve the health and resilience of ecosystems for the benefit of society. Indeed, Baró *et al.* (2016) reveal that the operationalization of ES mapping in decision-making for landscape and urban planning remains limited, and lacks a clear distinction between ES capacity, flow and demand that would enable planners and policy-makers to identify where ES are used unsustainably and where ES flow is failing to meet societal demand.

The publication of the EU Green Infrastructure Strategy (European Commission, 2013) should have helped to some extent – at least in Europe. The strategy aims to mainstream ES delivery in spatial planning through the consideration of nature-based solutions to societal issues, for example community allotments for improving social cohesion and reducing obesity, or green roofs and walls to help address climate change mitigation and adaptation (European Commission, 2013). However, Rinne and Primmer (2016) found that the ES concept was still not being embedded in urban planning processes or institutions in cities in Finland (with the exception of the cultural ES of recreation). In contrast, municipalities in southern Sweden *have* started to integrate the ES concept into their planning documents, as evidenced by Nordin *et al.* (2017). For example, five of the six study towns/cities mentioned ES explicitly in their planning documents (particularly those published in 2014 and 2015), with individual ES generally linked to specific

targets (e.g. a policy to plant trees on major streets to address air pollution) (Nordin *et al.*, 2017). Habitat provision and recreation/health were also comprehensively addressed in the majority of the Swedish documents – as was water regulation – though heat amelioration and air purification were only addressed by around half of the documents (Nordin *et al.*, 2017). A similar study of 39 Italian planning documents published since 2012 revealed the frequent detailing of actions to address urban ES provision, in particular relating to recreation, stormwater attenuation, air purification, heat amelioration, and noise reduction (Cortinovis and Geneletti, 2018).

One of the few North American studies published on the subject suggests that ES knowledge is fairly well implemented in Canadian municipal planning policy, with an average of 10% of plan content being devoted to discussing ES – though usually implicitly rather than explicitly (Thompson *et al.*, 2019). The most frequently mentioned ES in the 19 plans were aesthetics, stormwater attenuation, recreation and food production, though ES were typically discussed as bundles associated with natural habitats, urban forests, and green infrastructure. The study found the ES concept is often used to support and justify conventional planning approaches, has been introduced to deal with emerging challenges, and has been particularly useful for supporting urban place-making (Thompson *et al.*, 2019). Another Canadian study found four of 13 municipalities in the state of Ontario to have explicitly adopted an ecosystem approach to planning, though again, the term 'ES' is rarely used in the documents (Lam and Conway, 2018). Whilst recreation, habitat for wildlife and aesthetics were commonly mentioned in the reviewed plans, few or no references were made to air purification, stormwater attenuation and climate regulation.

Only one US study has been found, with Woodruff and BenDor (2016) comparing the treatment of ES in planning documents in the cities of Damascus, Oregon and Cincinnati, Ohio. Whilst the former had over 50 policies related to ES, the latter city did not include any such policies. Nevertheless, Hansen *et al.* (2015) reviewed planning documents in New York and Seattle in the United States, and Berlin, Salzburg, and Stockholm in Europe to understand how well ES have been integrated into urban planning in the two regions. They found that explicit references to the ES concept were largely only found in strategic planning documents from Stockholm and New York, though implicit references (e.g. to nature's benefits or ecological functions) were common for all cities but Salzburg. Interestingly, the concept of benefits was the most frequently referred to in the two US cities, and the least common in the three European cities. Hansen *et al.* (2015) found that habitat provision and cultural services (especially recreation and health) were most frequently emphasized, with regulating ES such as heat amelioration, stormwater attenuation, and air purification restricted to just over half of the 33 documents. Furthermore, whilst habitat provision and recreation/health were often supported by particular measures or targets, the

other ES were mainly addressed through high-level policies, with little information available on how to action these (Hansen *et al.*, 2015). Overall, there was no clear difference in the consideration of ES in planning in the United States compared to Europe.

2.1.2 Consideration of ecosystem services in urban forest management

This sub-section reviews ES literature relating specifically to urban forest planning and management, and finds a sharp contrast in the approach taken in North America compared to that in Europe. Researchers have found that staff responsible for urban forest planning and management in cities across Canada and the United States have been taking an ES approach for many years. Whereas in Europe, and particularly the UK, strategic urban forest policy has been slow to adopt an ES approach, resulting in limited on-the-ground action.

In Canada, a review of 14 urban forest master plans by Ordóñez and Duinker (2013) found that half of these took an ecosystems approach, and/or were based on i-Tree Eco studies. However, Ordóñez and Duinker (2013) felt that the plans were primarily focused on tree health, tree diversity and canopy cover, with "ecological, social, and economic considerations lack[ing] specificity and operational clarity" (p.36). Since the review was conducted, a national urban forest strategy was adopted by the Canadian government (Tree Canada, 2012), stressing the importance of trees in mitigating the urban heat island and air pollution problems. Consequently, urban forest master plans published in Canada after 2012 have been incorporating regulating ES into visions, strategic goals and operational principles, again supported by i-Tree Eco studies (e.g. see Toronto City Council, 2013). A more recent study by Fontaine and Larson (2016) found ES provision to be the second most important consideration in urban forest management in the province of Ontario (after tree establishment), with particular interest in temperature regulation and carbon sequestration services. In terms of funding, the working group behind the national urban forest strategy set themselves a task to "help secure strong and lasting financial commitment to develop and maintain urban forests" (Tree Canada, 2012: 7). However, Fontaine and Larson (2016)'s respondents cited staff shortages and constrained budgets as significant limitations to adapting their urban forest to climatic changes.

In the United States, Young (2013) sent a questionnaire to all 1,175 members of the Society of Municipal Arborists (the largest professional association representing US urban foresters) to find out about their efforts in managing municipal green space to produce ES. Of the 599 respondents, Young (2013) found 73% to be actively engaged in managing street trees, parks and natural areas to produce ES such as air purification, temperature regulation, carbon sequestration, woodfuel provision, stormwater regulation, water purification, and biodiversity. Furthermore, the study

suggests that local authorities in the United States are very supportive of their staff taking an ES approach to urban forest management, with strong support also coming from third sector organisations and residents (Young, 2013). In terms of funding, Tran *et al.* (2017) state that investments in urban forests have been increasing in many US cities, with afforestation projects focused on improving air quality, lowering temperatures, and increasing stormwater alleviation in cities. This may, in part, be down to the proliferation of i-Tree Eco studies carried out in the country; 33% of the 408 US towns and cities surveyed in 2014 by Hauer and Peterson (2016) had used the tool (or the 'i-Tree Streets' version) to quantify and value their urban forest ES. Furthermore, Soares *et al.* (2011) reported that cities such as New York, Boise, and Minneapolis have received additional funding and other support for their municipal forests as a result of monetizing the ES they provide.

Research on the subject in Europe is limited. A German study asked various stakeholders (including representatives from the forest administration and the department of urban planning of the city of Augsburg) which urban forest ES they considered most relevant in their city (Meyer and Schulz, 2017). For the foresters, timber, drinking water, mediation of climate and water, and recreation were all considered to be relevant; whilst for the urban planners, recreation was by far the most relevant ES. However, it is not clear to what extent these opinions influence urban forest planning and management in the city. A Polish study suggests that provision of cultural ES (opportunities for rest and recreation) are key principles of urban forest management in the city of Poznań, but states that there is no consistency in the management of Poland's urban forests (in contrast to their rural forests) (Jaszczak and Wajchman, 2015). The European grey literature also suggests a mixed picture; for example, urban forest strategies in Barcelona and Dublin refer to ES only in passing (Barcelona City Council, 2011; Dublin City Council, 2016). Helsinki's strategy puts 'securing ES' as its main objective, though delivering this only amounts to considering the effects of decision-making on the long-term vitality of ES provision (City of Helsinki, 2014). Sweden, Denmark and Switzerland all prioritise the provision of cultural services (e.g. recreation and education) in their objectives for urban woodland management (and to a lesser extent nature conservation), but regulating services receive very limited explicit attention (Nielsen *et al.*, 2013; Wilkes-Allemann *et al.*, 2015).

In UK planning policy, there was very little connection between urban forests and delivery of regulating ES until the publication of a government-commissioned synthesis report into forests and climate change (Read *et al.*, 2009). Chapter 10 of the report suggested that for urban forests to help society adapt to climate change, it would be necessary to address the information gap on the nature and extent of each local authority's urban forest, and to conduct further research on decision support systems which improve understanding of ES and associated economic benefits

(Handley and Gill, 2009). Since then, regulating ES have been increasingly integrated into national level planning policy in England, Scotland and Wales – however not in Northern Ireland.

For example, the Welsh Assembly Government (2009) committed itself to working with local authorities to ensure that the temperature regulation and flood regulation services of trees are taken into account in planning and development. Forestry Commission Scotland (2010) produced a guidance document to help local authorities ensure that their trees and woodlands deliver multiple benefits to society – particularly to address urban heat islands and winter storms. In England, a forestry strategy published in 2013 includes references to proactive local authorities working with the private sector to come up with innovative ways of financing urban tree planting, supported by the valuation of ES using the i-Tree Eco tool (Defra, 2013a). However, in Northern Ireland, the recently published regional forestry plans and national level opportunity mapping for woodland creation (DAERA-NI, no date) refer only to the provision of ES by rural forests.

Though moving in the right direction, strategic policy regarding urban forest ES remains uncoordinated and inconsistent across the UK, and a dearth of relevant academic studies means it is unclear to what extent regulating ES are being integrated into on-the-ground decision-making. Urban forest surveys conducted in England (Britt and Johnston, 2008) and Scotland (Van der Jagt and Lawrence, 2015) would suggest very little, as ES are barely mentioned in these documents.

Commissioned by the UK Government, the Trees in Towns II inventory report (Britt and Johnston, 2008) provides useful information on England's urban tree stock (obtained from tree surveys of 147 towns and cities) and its management by local authorities (obtained from 258 questionnaires to tree officers). Whilst the contribution of each surveyed tree to the urban environment was based in part on its shading, noise reduction and aesthetic qualities, ES provision was not explicitly discussed. Meanwhile, references to ES provision were entirely absent from the questionnaire, and thus also from the answers given. For example, decisions about which trees to plant were attributed mainly to the expected size of the tree at maturity, and the initial financial cost; not to the benefits it would provide. Nevertheless, Britt and Johnston (2008) (p.32) stated that tree officers must "become far more proactive in promoting the benefits of urban trees" if they are to be seen as public assets rather than as liabilities.[9] In Scotland, Van der Jagt and Lawrence (2015) provided a snapshot of the state of urban tree management by 22 local

[9] In the UK city of Sheffield, a highways contractor employed by the council has removed thousands of mature – often healthy – street trees due to actual and potential future root damage to pavements (Burn, 2018). Whilst the council and contractor may have seen street trees only as a liability, the (threat of) removal of the trees has caused residents to rally together in support of the trees, launching a campaign and numerous protests to stop the felling. As a result of legal and political investigations into the council's conduct, and widespread media coverage, the UK government has launched a consultation document to provide greater protection for urban trees, including the introduction of a duty for local authorities to consult on the felling of street trees (Defra, 2018c).

authorities, via questionnaires and telephone interviews. Despite being a fairly recent study, Van der Jagt and Lawrence (2015) did not ask respondents about ES provision; however some interviewees indicated that woodland strategies can help to highlight the benefits of trees (including flood prevention) to funders and landowners. Surprisingly, the update to this survey by van der Jagt and Lawrence (2019) still did not ask about provision of ES; but again the importance of tree and woodland strategies was highlighted for communicating the biodiversity, well-being and stormwater management benefits of trees to stakeholders (including politicians).

2.1.3 Socio-political constraints to adopting an ecosystem services approach

Whilst tree officers in North America take a proactive, ES approach to management activities (facilitated by urban forest strategies, i-Tree surveys, supportive local government and residents, and increasing budgets), there is currently little evidence to suggest that an ES approach is occurring on-the-ground in urban forests in Europe. Indeed, in the UK, it seems tree officers are instead taking a reactive approach to urban forest management due to a lack of funding and (perceived) poor public and private sector support.[10] Furthermore, the extent to which ES are being considered in planning policy and decision-making more generally across Europe and North America remains inadequate and inconsistent. A number of researchers world-wide have investigated why this might be, finding there to be a range of socio-political constraints; these are discussed below.

Turner and Daily (2008) identified three challenges in adopting an ES approach to decision-making: 'information failure', 'institutional failure', and 'market failure'. Information failure is described as a deficiency of detailed information linking ES with wellbeing benefits at scales useful for decision makers (Turner and Daily, 2008). More recently, Guerry *et al.* (2015) found that information failure is still preventing ES information from fundamentally changing decision-making across the world. As an example, Ojea (2015) reported issues of uncertainties around climate change and ES and how to measure their effectiveness limiting the mainstreaming of ecosystem-based adaptation into the international climate agenda. Foster *et al.* (2011) also reported that uncertainty surrounding ES provision is preventing its use in US municipal decision-making on urban climate adaptation. In contrast, Matthews *et al.* (2015) suggest that the wealth of published literature on the biophysical capacity of green infrastructure to help cities adapt to climate change means there is no longer an information failure, at least not in the British context.

[10] As local authorities receive complaints rather than praise about urban trees, it gives the impression that trees have little public support. However, it is possible that trees and their benefits are simply taken for granted; the Sheffield tree felling fiasco suggests that as soon as trees are threatened with removal, they receive much stronger and more widespread public support.

However, Rinne and Primmer (2016) suggest that scientists optimistically expect research on ES to infiltrate into planning and decision-making, with little consideration of its practical application or its institutional preconditions. Luederitz *et al.* (2015) add that scientific findings regarding urban ES are not being adequately translated into actionable knowledge for use in planning and management decisions. In Italy, Cortinovis and Geneletti (2018) lament the lack of usable methods to assess urban ES at the right scale and resolution for decision-making, whilst Lam and Conway (2018) suggest there is still confusion about the ES concept among planning practitioners in Canada, due to a lack of guidance on when and how the ES concept should be applied in the planning process. Indeed it seems that the excellent research on ES is simply not being presented in ways that are salient, credible and legitimate for instrumental decision-making (Wright *et al.*, 2017).

The second challenge, institutional failure, refers to local socio-ecological contexts being considered to an insufficient degree in decision-making (Turner and Daily, 2008). Guerry *et al.* (2015) also report a degree of institutional failure, suggesting that governments, businesses and civil society are not working together closely enough to ensure that ES are integrated into every day decision-making. Ojea (2015) similarly found evidence of poor governance structures, limited public participation and inappropriate financial mechanisms in the context of world-wide ecosystem-based adaptation. In the UK context, Matthews *et al.* (2015) also find that socio-political factors (including governance, funding and public involvement) are still poorly understood.

The third challenge, market failure, can occur due to issues of short-termism and free-riders (Turner and Daily, 2008; Guerry *et al.*, 2015). Ojea (2015) suggest that the short-term dynamics of decision-making failing to deal with the long-term nature of climate change is a particular challenge for the uptake of ecosystem-based adaptation. Green infrastructure also requires long-term planning and management, but often conflicts with incentives for short-term optimisation prevalent in industry and political arenas (Scott *et al.*, 2017). Faehnle *et al.* (2015) add that the multi-scale settings of ES supply and demand (i.e. differing timescales and spatial variation) are particularly problematic in urban planning, in part due to the poor consideration of such issues in the academic literature (i.e. information failure), and in part due to the mismatch with policy timescales (i.e. market failure).

A fourth challenge is identified by Naumann *et al.* (2011), who found examples of 'habitual modes of practice' restricting forward-thinking decision-making in their review of ecosystem-based approaches to climate change adaptation in Europe. Hansen and Pauleit (2014) suggest that traditional departmental structures in municipalities worldwide hinder establishing new ways of

systemic thinking and cross-disciplinary cooperation. Matthews *et al.* (2015) similarly found that 'path dependence', whereby decision-makers favour fixed patterns of thinking and lack motivation to respond meaningfully to new problems and solutions, is a significant constraint to adopting green infrastructure for climate adaptation in Britain. Scott *et al.* (2017) add that the multifunctional nature of green infrastructure conflicts with the 'silo' mentality of government departments in the UK. Wamsler (2015) also found a degree of path dependence amongst German local authorities, suggesting that ecosystem-based adaptation to heat and flood risk is unlikely to be integrated into cross-departmental decision-making unless departments have previously worked together on other cross-cutting issues (such as climate change mitigation).

Finally, Scott *et al.* (2017) suggest that green infrastructure and the ES it provides has yet to emerge as a core spatial planning concept in the UK "due to problems of perception; its negative environmental associations which conflict with a predominant economic growth narrative; [and] its elusive and intangible nature which inhibits its translation on the ground with sufficient quantifiable indicators and delivery mechanisms for its management and use" (p.5). Though not mentioning ES or climate change adaptation, the surveys of tree officers in England (Britt and Johnston, 2008) and Scotland (Van der Jagt and Lawrence, 2015) revealed strong evidence of socio-political constraints to proactive urban forest management. Mainly this constitutes institutional failure (i.e. poor support from and communication with the wider council, citizens and businesses), but information failure (i.e. limited data on the tree stock and awareness of tree benefits) was also apparent. Unfortunately, it seems that this lack of data, funds and staff is preventing UK tree officers from doing anything about the poor public and political image of urban trees; a concern given that this is likely to be locking them in to a downward spiral (the mass removal of supposedly problematic street trees in Sheffield is an extreme example of this). However, Britt and Johnston (2008) and Moffat (2016) both state that it is the responsibility of tree officers to ensure that the public and the council start to view urban trees as assets rather than as liabilities. Possible solutions to these socio-political constraints are discussed and critiqued below.

2.1.4 Recommendations to facilitate an ecosystem services approach to green infrastructure planning and management

In light of the information failure that is still preventing the integration of ES into urban planning decisions, Cortinovis and Geneletti (2018) recommend strengthening the information base on a wide range of urban ES, and analysing the multi-functionality of urban ecosystems at a relevant scale. A key recommendation of the UK Forestry Commission Working Group (2013) is to use valuation tools such as i-Tree Eco to demonstrate the economic benefits of trees in order to

upgrade their status and financing to equal those of other critical infrastructure such as utilities, transport and drainage (Forestry Commission Working Group, 2013). A similar conclusion was drawn from a green infrastructure case study in Bruges, Belgium, where Vandermeulen *et al.* (2011) show that putting a monetary value on green infrastructure can help to justify policy support for and investment in green space. However, Vandermeulen *et al.* (2011) add that it is necessary to communicate to decision-makers the restrictions and assumptions underlying the monetisation of ES, as the values will differ depending on the method used.

Hansen *et al.* (2015) suggest that using ES to support other policy issues, such as biodiversity protection, could help to mainstream ES in urban planning. Indeed, one of the identified factors for success of green infrastructure planning and implementation in European cities through the GREEN SURGE project was linking green infrastructure to pressing challenges such as flooding or heat islands (Hansen *et al.*, 2016). Hansen *et al.* (2019) go so far as to recommend the inclusion of standards and guidelines for multi-functionality (i.e. increasing the provision of multiple ES in synergy) in city-wide strategic planning, as it is the ability of green infrastructure to solve multiple urban issues at once that makes it so valuable. Thompson *et al.* (2019) add that relating information on ES to the multiple theoretical, political, institutional, technical, and economic contexts that influence the planning process could help improve its usefulness for decision makers.

To help address institutional failure, Hauck *et al.* (2013) suggest it is "essential for planners, citizens, ecologists, economists and social scientists to work more closely with one another" (p.235). The Forestry Commission Working Group (2013) recommends increasing involvement of citizens and businesses in urban forest management, for example through innovative public-private partnerships. However, public-private partnerships can be complex; Roe and Mell (2013) (p.667) found "the process of achieving multiple aims with the input of numerous stakeholders with unequal power" actually hindered the successful provision of benefits from greenspaces in Cambridgeshire, UK. Nevertheless, Hauck *et al.* (2013) advise that information on societal demand for ES (based on studies of preferences and values) is necessary if ES are to be integrated into spatial planning. Ordóñez Barona (2015) similarly recommends that ES approaches to urban forest management should incorporate public values (i.e. citizen preferences for specific ES and urban forest features) if local citizens are to be engaged and offer their support.

As part of the European Commission-funded GREEN SURGE project, Hansen *et al.* (2016) also identified involving citizens and other stakeholders as a factor for success of green infrastructure planning and implementation in European cities. Other factors identified by Hansen *et al.* (2016) for addressing institutional failure include identifying advocates amongst those with political

clout; supporting collaboration amongst different departments and disciplines; and increasing resource availability. The studied European cities achieved the latter point by sharing resources with similar existing programmes, involving different departments to fill resource gaps, encouraging voluntary participation from citizens, and accessing funds from developers and businesses (Hansen *et al.*, 2016).[11] In the UK context, Mell (2016b) identified alternative forms of funding for green infrastructure in Liverpool, including business sponsorship of trees and green spaces; organisations purchasing sites and managing them for public use; and increasing the size of development contributions to gain planning consent. Community-led funding is also discussed, though this largely relates to transferring management of publicly-owned green space assets to community groups, who may be eligible for certain grants (Mell, 2016b).

To address market failure and path dependence, Rinne and Primmer (2016) suggest that land-use planning requires institutional adaptation. In the context of implementing nature-based solutions in European cities, Frantzeskaki (2019) found that urban planners would benefit from an open approach to collaborative governance, enabling them to learn from other urban actors, and even to form new institutions. However, as well as encouraging planning practice to adapt and modernise, Rinne and Primmer (2016) suggest that attention needs to be shifted from ES concepts and valuation to embedding this knowledge in *existing* planning practices and institutions. Rinne and Primmer (2016) found that planning decisions in their case study areas in Finland are largely driven by formal obligations from legislation and higher-level land-use plans, so it is important that these are amended to advocate – or if possible, mandate – taking an ES approach to urban planning. The constraint of short-term political cycles would then be less relevant.

Finally, Kenney *et al.* (2011) proposed a framework of 25 community and resource management indicators against which local authorities in North America could evaluate the success of their urban forest management and planning. The purpose of such a framework is to help tree officers focus – in a proactive manner – on outcomes. The 25 indicators are similar to the constraints and solutions already discussed, and include: the level of interaction between the local authority, citizens and businesses; the level of awareness of the benefits of trees by the public; the level of private and public funding; the suitability of the location of the tree and the maintenance regime for provision of benefits and tree health; and the adequacy of the urban forest management plan. Whilst such a large number of indicators may seem onerous, Kenney *et al.* (2011) reveal that the framework had been successfully adopted in three Canadian municipalities.

[11] The potential for financial contributions from businesses and citizens are addressed in Objective 2 (section 2.2) and Objective 3 (section 2.3) respectively.

2.1.5 Conclusion and implications for the study

The worldwide ES literature suggests that socio-political constraints (in particular institutional failure, information failure, and path dependence) are preventing the integration of ES into government decision-making. Despite this, the literature reveals that (regulating) ES are being integrated into urban forest management in North America, however there is a gap in knowledge regarding the extent to which this occurs in the UK or elsewhere in Europe. What is clear, is that UK urban forest management is predominantly reactive, and hampered by low levels of funding and support from local council staff, businesses and citizens. A number of possible solutions to mainstreaming ES in decision making (successfully trialled in various locations) have been suggested to address these socio-political constraints, including the monetary valuation of local ES provision, and creation of innovative public-private partnerships to engender (financial) support for green infrastructure. Both of these could assist local governments in operationalizing ES in land-use planning, and in particular, improving the provision of urban forest ES.

This review has served to guide the development and delivery of Objective 1 of the thesis, which seeks to fill the gap in knowledge of whether, how and why (not) local authority tree officers are addressing regulating ES in their urban forest management. The findings of this review are also relevant to Objectives 2 and 3 of the thesis, which seek to identify business and citizen attitudes towards urban forest ES and the funding of these via new public-private partnerships.

2.2 Objective 2: Business attitudes towards investing in ecosystem services

This section of the literature review looks into the feasibility of improving levels of funding for urban forest ES from businesses, as part of an innovative public-private Payments for Ecosystem Services (PES) scheme. It starts by reviewing the extant literature on business attitudes towards ES, and corporate social responsibility (CSR) more generally. It then reviews studies on PES schemes involving businesses and/or urban areas in order to identify the likely factors of success for a future business-funded urban forest PES scheme.

2.2.1 Business attitudes towards investing in ecosystem services

Very few studies have investigated business preferences for ES or their attitudes towards trees – indeed, only one author has captured business views on urban forest ES (Wolf, 2004b, 2004a). Interestingly, these studies are based on data gathered around the turn of the millennium – before concepts such as ES had been fully established, or CSR had become a widespread activity.

More recently, two studies (Brewer *et al.*, 2014; CLES and TWT, 2015) have investigated business interest in paying for ES from urban rivers, whilst Koellner *et al.* (2010) and Reed *et al.* (2013) have looked into whether businesses are willing to invest in ES produced by tropical forests and peatland, respectively. The results of these studies are discussed in turn, below.

Wolf (2004a) asked the owners/managers of retail businesses located in seven US cities what benefits and annoyances they associate with city centre trees. A total of 165 businesses responded, along with 252 local residents (out of 3,500 mailed during spring 1998). Wolf (2004a) found that businesses showed less interest in all 15 listed tree benefits than residents (though benefits were similarly ranked by the two groups). Only visual amenity was considered to be of major benefit to business owners/managers, though heat regulation, nature connections, air purification, and noise reduction were rated as moderate benefits (Wolf, 2004a). Tree annoyances were more problematic for businesses than residents, however both groups rated tree benefits as more important than tree annoyances overall. Of the 16 listed annoyances, trees blocking business signs, and the damage that tree roots cause to pavements and sewers were considered moderately important to businesses (Wolf, 2004a). Trees growing into utility cables, leaf fall, bird droppings, and trees reducing street safety (by blocking views and streetlights) were of minor importance. Interestingly, Wolf (2004a) found leaf fall to be significantly more problematic for businesses than residents, as it is the responsibility of the business owners/managers to clear the leaves (associated with potential accident/liability) which adds to business costs.

A second study carried out in 2002 involved face-to-face interviews with 365 shoppers in a business district in Georgia, United States – 56% of whom also worked in the business district (Wolf, 2004b). Contrasting with the author's earlier study, those working in the business district were more keen on trees than the other shoppers, leading the author to suggest that "green streets may contribute to employee satisfaction" (Wolf, 2004b: 339). This is supported by other studies which suggest that green space in the vicinity of business premises can reduce stress and thus increase productivity (Kaplan, 1993; Miller, 1997; Rolls and Sunderland, 2014). Though the interview questions did not specifically cover ES or disservices this time, Wolf (2004b) recorded 92 comments about tree benefits (particularly heat regulation, air purification, noise reduction, biodiversity and visual amenity), and none relating to tree annoyances. Wolf carried out several more studies in US cities during the following years. Though these all focused on retail customers rather than the businesses themselves, one finding is of particular relevance to businesses. Wolf (2009) found that customers not only travel further and more often to retail areas with trees, but they are also willing to pay around 10% more for equivalent goods and services in such areas. This suggests that trees in the vicinity of retail businesses can increase sales revenue.

In the UK, the 'River Irwell PES pilot study' investigated commercial business preferences for paying to enhance the ES provided by the River Irwell in Manchester and Salford city centres (CLES and TWT, 2015). Visual amenity was found to be of interest to businesses operating in the leisure, tourism and catering/hospitality industries; two of which made use of the river view in their marketing material (though only one considered this to have commercial value). However, not one of the businesses was willing to pay to enhance the river's aesthetic benefits (CLES and TWT, 2015). The ES of water quality enhancement, biodiversity and recreation received only very limited interest amongst respondents, whilst flood and heat regulation (the two services considered by the council to be the most important in the area)[12] received no business interest at all (CLES and TWT, 2015). The lack of interest in river ES was found to be because businesses felt no moral duty to their local environment, and they did not consider there to be any commercial benefit to their organisations from investing in such services (CLES and TWT, 2015). Another UK PES pilot study, the 'River Lea in Luton', was more successful in delivering tangible outcomes – leading to the development of a Catchment Partnership including two major local businesses – though there is still no operational PES scheme in the town (Defra, 2016a). Brewer *et al.* (2014) found Vauxhall Motors and Luton Airport to be motivated by reducing their environmental impact on the river, and suggest that, even at early stages of PES development, it is "important to establish what priorities businesses might have in working with their local communities as part of their CSR agenda" (p.48).

Koellner *et al.* (2010) used contingent valuation to identify business willingness-to-pay (WTP) for ES provided by tropical forests in Costa Rica – namely watershed protection, carbon sequestration, biodiversity conservation and scenic beauty. Of 988 firms contacted, 60 took part in the study, and 75% of these were willing to invest in ES. Koellner *et al.* (2010) found no statistical difference in preferences based on business sector (industry, consumer and financial) or number of employees, but a statistically significant difference in opinion between the 31 international and 29 Costa Rican firms. The latter group were willing to invest in all four ES (especially watershed protection given the dependency of many of these businesses on water resources), but international firms were only willing to pay for carbon sequestration. Koellner *et al.* (2010) also asked businesses what factors would influence their decision to engage in such a PES scheme, and were surprised to find that 'human welfare' and 'ecological responsibility' were the greatest drivers, along with 'image benefits'. However, with just 6% of contacted businesses

[12] An ecosystem service mapping project undertaken in Greater Manchester (Greater Manchester Environment Team, 2014) identified six priority ecosystem services within or just upstream of the 'River Irwell' pilot study area. Highest priority were flood and heat regulation; of medium priority were visual amenity, recreation and water quality; with biodiversity a low priority.

taking part in the study, Koellner *et al.* (2010) note that intrinsic motivations are unlikely to be sufficient for a PES scheme, and so a business case would likely be needed.

Carbon sequestration was also found to be the ES of most interest amongst the 15 businesses (three SMEs and 12 larger corporations) interviewed in the UK Lake District for the 'Peatland Code PES pilot study' (Reed *et al.*, 2013). As the Peatland Code is a voluntary standard for UK peatland projects wishing to market the carbon sequestration benefit of peatland restoration to private investors, this is not surprising. On the other hand, Peatland Code sponsorship can only be used towards CSR objectives, and not for carbon offsetting.[13] Perhaps because of this link to CSR, the 15 interviewed companies were also keen to pay for co-benefits such as enhanced biodiversity, and water quality/quantity benefits. The interest in enhancing biodiversity related partly to the increased number of visitors and tourists that biodiverse habitats can attract, and partly to "stakeholder and customer concerns" (Reed *et al.*, 2013: 111). Meanwhile, water/utility companies and those with large water usage were interested in reducing their business costs and showing that they "are taking action to mitigate adverse impacts on the aquatic environment" (Reed *et al.*, 2013: 111). It has been suggested that linking carbon sequestration with CSR (as opposed to a formal carbon market) ensures that the co-benefits of water quality, biodiversity and recreational opportunities are valued in their own right, to the extent that investors are often prepared to pay more to secure them (Rabinowitz and d'Este-Hoare, 2010; Bonn *et al.*, 2014).

2.2.2 Motivations for undertaking environmental corporate social responsibility

Due to the very limited number of studies that have investigated business interest in (paying for) ES, it has been necessary to widen the scope of this literature review to include business involvement in environmentally-focused CSR activities, and their motivations for this. A review of such studies has provided further insight into whether businesses might be willing to pay for enhancement of natural capital and the ES it provides, as opposed to more typical environmental measures relating to energy or waste reduction.

Of the 37 different definitions of CSR identified by Dahlsrud (2008), the most commonly cited definition was found to be that of the European Commission (2001) (p.6), i.e. "a concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis". This sub-section explores whether businesses might consider enhancement of urban forest ES as part of their wider CSR.

[13] This is because there is currently no government accounting of peatland carbon savings (IUCN, 2015).

Rondinelli and Berry (2000) conducted a study on the environmental reports of 38 UK-based multinational corporations, dividing CSR activities into external and internal practices. External practices were found to include: financial support for employees participating in community environmental improvement activities; developing and preserving wildlife habitats on or near company premises; undertaking voluntary remediation of natural resources degraded by business operations; and preservation and replanting of forests. However, Rondinelli and Berry (2000) note that such practices are ad hoc, and represent only a tiny fraction of what is spent on internal environmental practices such as reducing energy and resource use, recycling, and at-source pollution prevention measures. This suggests that businesses may be motivated more by direct benefits (e.g. cost reductions) than moral incentives.

According to Meißner (2013) (p.148), "there are two drivers of corporate environmental responsibility that are emphasized in literature: the image effect of environmental commitment; and the mitigation of corporate ecological risks (e.g. natural disasters, depletion of resources)". A later study involving interviews with 39 German businesses revealed the four most important CSR drivers to be improving the company's image; increasing its shareholder value; following the wishes of management and customers; and gaining a competitive advantage (Meißner and Grote, 2015). These are similar to the five drivers identified by Weber (2008): improving company image and reputation; enhancing employee motivation, retention, and recruitment; making cost savings; increasing sales and market share; and reducing exposure to risk. Again, these drivers relate overwhelmingly to benefitting the company, rather than to benefitting the environment or society. Indeed, Meißner and Grote (2015) state that only when a business case is developed and direct benefits are guaranteed, would most companies in the study be willing to invest in ecosystem conservation projects.

However, it has been argued by many authors (e.g. Kohlberg, 1981; Goodpaster, 2007; Baden, 2016) that CSR is – and needs to be – a moral concept, with social concerns prioritised over economic concerns. For example, Moore (2008) (p.509) suggests that businesses emitting large quantities of greenhouse gases have remedial "duties to mitigate future effects of global climate change, including… planting trees to absorb greenhouse gases". Whilst there is some evidence of businesses having moral motives, this can be hard to distinguish from social legitimacy, e.g. offsetting adverse impacts on the environment or considering the environmental concerns of employees (Reed *et al.*, 2013; Meißner and Grote, 2015).

2.2.3 Defining and developing payments for ecosystem services

PES is not the only way to increase funding for the ES provided by urban forests and other green infrastructure. However, for this particular funding mechanism to be taken seriously by local and national governments (as well as other stakeholders and beneficiaries), it is necessary to clarify what is being proposed, and how it might be applied. This sub-section therefore introduces the concept of PES, the criteria typically associated with PES schemes, and what aspects need to be considered in the early stages of PES development.

The first formal definition of 'Payments for Ecosystem Services' (PES), and one of the most frequently quoted, describes PES as: "(1) a voluntary transaction where (2) a well-defined ES (or a land-use likely to secure that service) (3) is being 'bought' by a (minimum one) ES buyer (4) from a (minimum one) ES provider (5) if and only if the ES provider secures ES provision (conditionality)" (Wunder, 2005: 3). Another key criteria is that of 'additionality', whereby the providers are paid to undertake activities that they would not undertake without that compensation (Engel *et al.*, 2008). The definition used in the UK is similar, with Defra establishing the following seven principles for PES schemes: voluntary; beneficiary pays; direct payments; additionality; conditionality; ensuring permanence; and avoiding leakage (Rowcroft *et al.*, 2011; Smith *et al.*, 2015).

However, the vast majority of active PES schemes fail to meet the conditionality criteria because of the difficulty (and cost) of measuring the actual flow of ES provided (Kroeger, 2013). Some schemes require 'input' conditionality, whereby payments are made based on a change to land use or management practices that are *assumed* to result in ES delivery (Kroeger, 2013), but in most schemes, payments are based simply on good faith and trust (Muradian *et al.*, 2010; Hausknost *et al.*, 2017). For example, due to concerns about costs, the UK Peatland Code provides potential funders with information about likely ES delivery for a site based on published scientific evidence, but does not require monitoring of this (Reed *et al.*, 2013). Furthermore, many active PES schemes involve governments or water companies paying on behalf of citizens or customers, whilst 'hybrid' schemes involving combining government and user financing are also common in practice (Wunder *et al.*, 2008; Vatn, 2010; Schomers and Matzdorf, 2013). Consequently, not all PES schemes involve voluntary or direct payments by beneficiaries.

Muradian *et al.* (2010) argue that the original definition of PES is overly restrictive and unrealistic, and redefine the concept as "a transfer of resources between social actors, which aims to create incentives to align individual and/or collective land use decisions with the social interest in the management of natural resources" (p.1205). The latter definition is much broader than the original definition of Wunder (2005), and allows for 'PES-like' market-based instruments such as

biodiversity offset schemes, green taxes, and agri-environment schemes (some of which long pre-date PES or even ES terminology). However, authors such as Matzdorf *et al.* (2013) are critical of the inclusion of market-based instruments in the PES definition, given the importance of the specification of a clear ES objective. A recent survey of over 150 environmental professionals from across the UK supports the definition of Muradian *et al.* (2010) over the original, as when asked to describe PES in their own words, very few mentioned the need for transactions to be voluntary, conditional, or additional (Martin-Ortega and Waylen, 2018). Furthermore, only a minority of those environmental professionals considered polluter-pays schemes such as offsetting or green taxes to be entirely separate from PES schemes (Waylen and Martin-Ortega, 2018), suggesting that the 'beneficiary pays' principle may not be required.

Due to the differences between PES theory and the roll-out of schemes in practice, Martin-Ortega and Waylen (2018) do not advocate imposing a universal definition of PES, but instead emphasise the importance of eliciting the 'understandings and expectations' of all PES actors in the early stages of scheme development. Important aspects to consider and elucidate when designing a PES scheme are listed below.

- The specific ES being targeted, and whether these are clearly defined;[14] what is actually being paid for (e.g. a change in land use); who the providers/sellers are; who the buyers and other (non-paying) beneficiaries are; and the spatial scale (Wunder *et al.*, 2008).
- The form of the payment (e.g. lump sum, rate per unit of input/output, tax, or subsidy); whether intermediaries are involved, and who they are; and the eligibility rules for participation (Jack *et al.*, 2008).
- The importance of the economic incentive (on both sides), as opposed to intrinsic, cultural or other motivations for enhancing ES provision (Muradian *et al.*, 2010).
- Whether the scheme is voluntary; how many actors are involved on each side;[15] whether the improvement to the services is qualitative or quantitative; whether one or multiple ES are the focus;[16] the frequency and timing of payments; the expected life of the scheme; and whether there are any negative or positive side effects (Sattler *et al.*, 2013).

[14] The ES most commonly featuring in PES schemes are 'watershed protection' (which typically relates to water purification, and sometimes to the regulation of water quantity/flooding), 'carbon sequestration', 'biodiversity conservation', and 'landscape beauty' (Escobar *et al.*, 2013; Sattler *et al.*, 2013).

[15] A monopsony has many sellers but only one buyer, e.g. where a government or water company pays multiple land owners; whilst a polypoly has many sellers and many buyers – for example, the Woodland Carbon Code whereby payments are made by many businesses to many land owners. Other possibilities include a monopoly, with only one seller but many buyers; and a bilateral monopoly, with one seller and one buyer (Sattler *et al.*, 2013).

[16] Most PES schemes sell only a single ES (e.g. enhanced water quality), but government-funded schemes are increasingly being drawn towards selling multiple ES together in order to optimise overall ES provision (Kemkes *et al.*, 2010; Sattler *et al.*, 2013). ES can be bundled together as one package; sold individually in layers/stacks (where each

- Who holds the decision-making power over where and how the money is spent; whether all affected parties get a say; and whether inequalities in access to and use of natural resources will be reduced or exacerbated (Van Hecken *et al.*, 2015; Campbell and Gabriel, 2016).

In the case of possible urban forest PES schemes, it is likely that local councils will be the sellers, and businesses (and perhaps citizens) will be the buyers (i.e. a monopoly). However, the academic PES literature almost entirely ignores the fact that the government could be a *provider* of ES, either with or without legal influence on the private sector to purchase these. One exception is Sattler *et al.* (2013) who concede that ES sellers are typically land owners, and as such this can include the government. However, Sattler *et al.* (2013) (p.35) mention that "there is an ongoing discussion if public land should be eligible for PES, as the state has the responsibility to safeguard public goods provision and should manage public lands accordingly". For example, Tacconi (2012) suggest that PES can legitimately be applied to state-owned land, but only by paying contractors or private individuals owning adjacent land to produce the ES on the state's behalf. Meanwhile, the grey PES literature in the UK (MacGillivray and Wragg, 2013; Eves *et al.*, 2015), and a research study in the United States (Poudyal *et al.*, 2010), suggest that governments prefer to act as sellers (or intermediaries), rather than as buyers.

2.2.4 Criteria and characteristics for successful payments for ecosystem services schemes

If urban forest PES schemes are to be successfully designed, developed and implemented in future, it is important to learn from the successes (and failures) of existing PES schemes. This sub-section therefore considers what it is about PES schemes that has made them, or ought to make them, successful.

An obvious problem in determining whether a PES scheme is successful or not is the absence of a common definition of PES success, or a set of agreed criteria against which to measure success. Based on input from environmental professionals from the United States and Germany, Sattler *et al.* (2013) concluded that a PES scheme can be considered successful if it exhibits effective and cost-efficient achievement of an ecological goal (beyond regulatory requirements), whilst also having positive side-effects (e.g. ES synergies or improved social cohesion). Grima *et al.* (2016) (p.26) has similarly defined PES success as "a combination of (a) the extent to which the original or defined goals of the PES scheme were met, and (b) the added value in terms of an overall

buyer can choose the ones they prefer); or payments for one key ES lead to the production of additional services for free, known as piggy-backing (Wertz-Kanounnikoff *et al.*, 2011).

improvement of the ecological, economic and social conditions of the region, beyond intended objectives", based on a review of 40 PES schemes in Latin America.

From a sample of 22 supposedly 'successful' PES cases from the United States and Germany, Sattler *et al.* (2013) found the most commonly used criteria to determine success were 'effectiveness' and 'efficiency',[17] though criteria such as 'acceptance', 'uptake', 'legitimacy', 'transparency', and 'equity' were also sometimes used. Vatn *et al.* (2011) consider the '3Es' of effectiveness, efficiency and equity to represent 'legitimacy of outcomes', whilst they propose 'legitimacy of the process' as an additional criterion of PES success (relating to how decisions are made, who participates, and under what conditions). These success criteria were adapted by Prokofieva and Gorriz (2013) who further split 'legitimacy of the process' into flexibility, implementation complexity, and acceptability. For each of these three outcome and three process evaluation criteria, Prokofieva and Gorriz (2013) provide a detailed definition and a number of indicators. Unfortunately, no papers have been identified that have used (let alone referenced) Prokofieva and Gorriz (2013)'s evaluation criteria of PES success, so its usefulness is unknown.

As PES payments tend to be made based on assumptions and good faith rather than evidence of ES delivery, environmental and cost-effectiveness are usually impossible to determine (Kroeger, 2013; Hejnowicz *et al.*, 2014). However, even for PES schemes requiring output-based conditionality, there is great uncertainty about the delivery of ES (Derissen and Quaas, 2013; Lockie, 2013; Lima *et al.*, 2017). A common response to the issue of scientific uncertainty around environmental effectiveness in PES schemes is to request more research (e.g. Farley and Costanza, 2010). However, research is expensive and time-consuming, and can only reduce rather than eliminate uncertainty given the complexity and stochastic nature of socio-ecological systems (Muñoz-Piña *et al.*, 2008; Muradian *et al.*, 2010; Barnaud and Antona, 2014). Because of this, a number of authors (e.g. Glenk *et al.*, 2014; Hamel and Bryant, 2017; Lima *et al.*, 2017) have called for outcome uncertainty to be explicitly communicated and accounted for in the early stages of PES development so as to avoid disappointment and mistrust later on. Aside from hypothetical willingness-to-pay studies (discussed in sub-section 2.3.3), the literature does not seem to discuss the effect of outcome uncertainty on the buyers of PES schemes. One exception is Thompson (2018) who interviewed corporate buyers from three active PES schemes in Thailand. With monitoring only of inputs, corporate buyers were dubious of the delivery of benefits, but trusted

[17] Jack *et al.* (2008) (p.9466) defined these terms as follows: "To be environmentally effective, a project must deliver a set level of environmental benefits, as defined by physical measurements. To be cost-effective [sometimes referred to as 'efficient'], a policy must achieve the same level of environmental benefits at a lower cost than other possible policies".

that their involvement would facilitate their marketability as 'sustainable' businesses (Thompson, 2018).

Perhaps due to the absence of an agreed definition and criteria of PES success, and the lack of output-based monitoring, Sattler *et al.* (2013) and Grima *et al.* (2016) both find that detail on the success of PES schemes is rarely documented, and often, only value judgements are presented. Consequently, the authors of both studies suggest that the design aspects referred to in the previous sub-section should be used to review apparently 'successful' (or unsuccessful) PES schemes. Sattler *et al.* (2013) found the characteristics most common to the 22 'successful' US and German PES schemes were:

- Involvement of an intermediary (present in 82% of cases);
- Involvement of governmental actors (70% of cases);
- A contract length of more than 10 years (68%);
- Positive side effects, e.g. relating to other ES, social cohesion, etc (also 68%);
- Voluntariness (for at least one side) in entering the PES agreement (60%); and
- Design of PES as output-based schemes to ensure conditionality (36% - this was considered very high as input-based schemes are far more common).

These results support findings by Muradian *et al.* (2010), Vatn (2015) and Hausknost *et al.* (2017) that intermediaries – which are typically NGOs, governments or public-private trusts – are crucial for PES success. In particular, intermediaries have the capacity to reduce transaction costs, provide information, and even use their own funds for PES scheme implementation (Vatn, 2010; Matzdorf *et al.*, 2013; Defra, 2016a). However, Escobar *et al.* (2013) reported that by reducing direct contact between buyers and sellers, the intermediary in their German case study actually restricted trust formation. Furthermore, Schomers *et al.* (2015) report that there has been limited research into the impacts of intermediaries on the effectiveness and efficiency of PES schemes.

Though not mentioned by Sattler *et al.* (2013), many other authors (e.g. Engel *et al.*, 2008; Prokofieva and Gorriz, 2013; Hausknost *et al.*, 2017) suggest that the relationship between actors – including the institutional arrangements and governance structures of PES schemes – is also crucial for PES success. For example, Prokofieva and Gorriz (2013) (p.112) suggest that PES schemes require: "consensus regarding the nature of the problem and its solution; positive attitude and networking capacity of actors; concordance of values; and actors' involvement in programme design". Matzdorf *et al.* (2013) add that successful PES schemes should be informed by the motivations of different actors, including internal or external rewards/obligations. Finally, Escobar *et al.* (2013) suggest that success is facilitated by the presence of 'champions' and a permanent contact person, trust amongst actors, and rules that can be understood and followed

by all parties. However, it should be noted that "there is no one-size-fits-all arrangement for the successful implementation of a PES program" (Kemkes *et al.*, 2010: 2074).

2.2.5 Business involvement in payments for ecosystem services schemes

This thesis proposes the development and implementation of urban forest PES schemes funded by businesses. For this to be feasible, it is important to understand whether active PES schemes where businesses are involved as buyers have been successful, and what motivated the businesses to get involved in these schemes.

The literature suggests businesses tend to be involved mainly in schemes selling water quality/quantity services. This often involves a single water-related company paying farmers upstream to switch to cleaner land management. Three long-running examples of this include Vittel in France, Munich City Utilities in Germany, and United Utilities in the UK. These schemes have been considered 'successful' for the following reasons: involving all stakeholders in scheme development; building up trust and understanding between stakeholders; strong leadership; and clear benefits to local habitats (Perrot-Maître, 2006; Tinch, 2009; Escobar *et al.*, 2013).

Two recent studies have used interviews with corporate buyers of PES schemes in the United States and Thailand (utility companies and others reliant on water such as aquaculture and beverage companies) to ascertain what drove them to invest. Bennett *et al.* (2014) found the US firms to be motivated by reducing their exposure to risk (regarding wildfire or pollution from developments); avoiding additional costs (e.g. new water treatment facilities); and/or regulatory compliance (whereby polluting firms are able to purchase offset credits). In contrast, the Thai firms viewed PES as a tool for philanthropy (i.e. 'giving back' to the environment), public relations, and gaining a social license to operate (Thompson, 2018). However, through interviews with water-dependent industries in the UK, Eves *et al.* (2015) found that there is still some reluctance to engage in PES schemes, due to a lack of knowledge and understanding about the benefits of PES, a perceived lack of regulatory or market pressures, and concerns about free riders. Eves *et al.* (2015) therefore recommend communicating the key successes and lessons learnt from other watershed PES schemes with these businesses. Bennett *et al.* (2014) similarly suggest that interest by utility companies could be enhanced by demonstration of the financial benefits to the company from investing in water purification and related ES (i.e. the 'business case').

The literature also suggests that businesses are increasingly involved in schemes selling carbon storage/sequestration services, such as carbon offsetting schemes. According to Hamrick and Goldstein (2016), most carbon credits worldwide are purchased by businesses from the events/entertainment, service, energy, transportation, and finance/insurance sectors. The specific

offset projects chosen by these businesses depends on their cost, provision of co-benefits (e.g. other ES or social benefits), and the 'fit' with their organization's mission (Hamrick and Goldstein, 2016). Laing *et al.* (2015) also found that businesses prefer to invest in carbon schemes that are closely aligned with their business activities (e.g. linking in with CSR and portfolio diversification). Surveys and interviews with businesses investing in the UK's Woodland Carbon Code suggest they are mainly driven by being 'seen to be doing the right thing', whilst the wider CSR and direct business benefits were also considered important (Camargue, 2015). However, one of the best known international carbon PES schemes, the UN's REDD+, has struggled to pique the interest of the private sector due to concerns over scheme complexity, compliance costs, additionality, leakage, permanence, indigenous rights, and corruption (Laing *et al.*, 2015).

2.2.6 Payments for ecosystem services schemes in urban areas

Despite the wealth of PES schemes operating in rural areas worldwide, no examples of active PES schemes in urban areas have been found. Whilst this makes the proposal for urban forest PES schemes novel, it is necessary to explore reasons why this has not yet been attempted, as this could perhaps make the concept unfeasible.

Having said that, there are probably many urban schemes with similar objectives, just without the PES scheme label. Two UK examples are discussed by Smith *et al.* (2015): in Portishead, North Somerset, a developer paid for the creation of a nature reserve adjacent to new housing, the maintenance of which is paid for via a levy on the new property owners. Similarly, in south-west London, a levy on households within 0.75 miles of Wimbledon and Putney commons pays for the majority of the site maintenance, enhancing cultural benefits (Smith *et al.*, 2015). Also in the UK, TreeTime Edinburgh (2015) is a social enterprise which offers corporate sponsorship packages to support tree planting in the Scottish city, however take-up has so far been limited (Darke, 2019). Meanwhile, 'Plant Your Postcode' has recently been launched in the UK city of Brighton to encourage community and corporate donations towards local tree planting (CPRE Sussex, 2019).

Over in the United States, a non-profit organisation (City Forest Credits, 2017) has had success selling carbon and quantified co-benefit credits to urban forest projects in cities nationwide; while another (NatureVest, 2017) has launched a private-to-private stormwater trading market in Washington D.C. to facilitate developers in funding green infrastructure projects to reduce stormwater runoff in the city. In Australia, the City of Melbourne (2018) has launched an 'Urban Forest Fund' seeking to match-fund contributions from organisations and individuals in order to pay for 40,000 new trees in the city, though it has received more interest from residents than

businesses so far. The PadovaO2 project in Italy has been more successful, planting 2,500 city trees from €50,000 of business donations (Wow Nature, 2018).

According to MacGillivray and Wragg (2013), the shortage of urban PES schemes compared to rural ones may be because the link between land use/management and ES delivery is far less certain in urban than rural areas. Based on the results of interviews with local authorities, Eves *et al.* (2015) add that applying PES to urban contexts is particularly challenging because costs and benefits are less clear than in rural areas, and there are far more people involved. Indeed, the large numbers of heterogenous, fragmented providers and beneficiaries (largely due to complex land tenure) in urban areas may mean that the transaction and implementation costs of a PES scheme exceed the amount buyers are willing to pay (Wunder, 2008). Furthermore, Wertz-Kanounnikoff *et al.* (2011) suggest that the large number of beneficiaries in an urban environment also increases the likelihood that they will free-ride on a much smaller number of paying users, thus undermining the overall willingness-to-pay for ES. Locating and contacting potential buyers in an urban context can also be far from straightforward – this was a problem for both the Luton and Irwell PES pilots (Defra, 2016a). For these reasons, a potentially very lengthy period of inter-organisational working may be required to establish a successful public-private PES partnership (Brewer *et al.*, 2014; CLES and TWT, 2015).

2.2.7 Conclusion and implications for the study

There is currently very little published information on business preferences and motivations regarding trees and ES, and little evidence of business involvement in PES schemes – especially in urban environments. Nevertheless, the literature suggests that despite the presence of moral incentives, most businesses are only willing to invest in the environment if there is a clear link between enhancement of the ES and the success of their business (either directly through reduced costs, or indirectly through an improved image). As such it will be important to provide potential corporate funders of an urban forest PES scheme with a business case, highlighting the link with CSR. In terms of 'successful' PES implementation, stakeholder involvement in programme design, understanding of stakeholder motivations, and trust between stakeholders (enhanced by the involvement of intermediaries) appear to be beneficial. If an (urban forest) PES scheme funded by corporate beneficiaries is being considered for a particular locality, it therefore seems wise to engage local businesses in discussions at as early a stage as possible. Once a scheme is up and running, some level of monitoring is required (ideally of outputs) to ensure environmental and cost-effectiveness – though uncertainty about the delivery of ES cannot be avoided, and so should be communicated with all stakeholders.

This review has served to guide the development and delivery of Objective 2 of the thesis, which seeks to fill the gap in knowledge of whether, why, and under what conditions businesses might be willing to invest in urban forest ES. The review provides context for the development and implementation of an urban forest PES scheme, regarding how extant PES schemes have been designed, and what has made them successful – particularly those funded by businesses or operating in urban areas. The findings of this review are also relevant to Objective 3 of the thesis, in particular regarding the creation of a 'PES scenario' incorporating outcome uncertainty that will form the basis of the citizen choice experiment.

2.3 Objective 3: Citizen preferences and willingness-to-pay for ecosystem services

This section of the literature review looks at citizen[18] attitudes towards urban forest ES, and paying for their delivery. It starts by comparing and critiquing published studies that have obtained citizen preference information for the different ES provided by urban forests (i.e. nature's contributions to people). It then reviews the published stated preference valuation literature, in particular by comparing willingness-to-pay (WTP) values for urban forest enhancement (i.e. people's contributions to nature). Finally, it looks at uncertainty in the delivery of ES, and how this affects people's WTP for them.

2.3.1 Nature's contributions to people – who values what, and why?

A review of 463 articles on urban ES (dated 1995-2012) by Hubacek and Kronenberg (2013) reveals a number of different perspectives on the value of urban ES, including economic, socio-ecological, psychological, and cultural, and that these often depend on people's socio-demographic backgrounds. Sander and Zhao (2015) suggest that, in addition to understanding *who* values green infrastructure, it is necessary to understand *where* (i.e. how values vary spatially

[18] It should be noted that, whilst Chapter 1 of this thesis defined 'citizens' as 'members of the public', the stated preference literature in fact makes a distinction between preferences of individuals in the role of 'consumer' versus the role of 'citizen' (Nyborg, 2000). As a consumer, individuals make choices as if they are paying for the good or service with their own money, and they alone realise the benefit (reflecting individual values). By contrast, citizens make choices about how they think the government should spend (existing) taxes for the benefit of society (reflecting shared values). In a travel choice setting, Mouter and Chorus (2016) found that WTP from a citizen perspective is far higher than WTP from a consumer perspective – partly due to a reluctance to spend one's own money. As most studies ask respondents to pay a hypothetical tax or charge (including many of those reviewed in this section) they are therefore considered to be consumers rather than citizens. However, in this thesis, it is considered more important where the money is going, and not where it has come from. If payments are to fund a public (non-rival, non-excludable) good or service – for example city-wide tree planting focused on provision of regulating ES, as in the case of Paper 3 – then it seems that respondents are more likely to be acting as citizens, with wider society in mind. Any influence of this distinction on WTP values is not considered further in this thesis, and only the term 'citizen' is used hereafter.

within a city), and *why* (i.e. what factors influence these values). For example, an urban woodland may be considered beneficial by inhabitants of one location, but cause problems to certain people in another. Lafortezza and Giannico (2019) add that accounting for the different perspectives of citizens is helpful for understanding where financial investments in green infrastructure will benefit the most people, as well as what types of green infrastructure should be implemented. Any planning decision that may affect the provision of urban ES "needs to be based on a careful analysis and management of the different perspectives on the value of those services" (Hubacek and Kronenberg, 2013: 5).

Twenty-two peer-reviewed papers identifying citizen preferences for a range of urban forest ES have been reviewed for this sub-section. To ascertain possible penchants for one category of ES over another, only papers which cover at least two different ES categories were reviewed. Consequently, 16 of those reviewed identify preferences for regulating and cultural services,[19] whilst the remaining six papers additionally include provisioning services. Furthermore, only studies from temperate, developed cities (i.e. potentially similar to Southampton) were used. The majority of studies were therefore conducted in North America (n=10) or Europe (n=9), with the remaining three occurring in Australasia (n=2) and Asia (n=1). Eighteen studies obtained citizen preference data through questionnaires, whilst three used focus groups, and one used secondary data.

In each of the studies, respondents were either required to rate a number of specified ES (e.g. via a Likert scale), or to identify those of most importance to them. These exercises enabled the authors to rank their studied ES in order of stakeholder preference. The following table (Table 2.1) ranks all of the 28 identified ES, firstly by the number of papers that mention them (frequency/22), and secondly by the total score calculated for each ES (score/22). The latter involved scoring each ES based on how well it ranked in each paper, and then summing these scores. For example, if a particular ES was ranked first by respondents from a list of nine ES showed to them, then it received a maximum score of 9/9 = 1, whereas the ES ranked last in that same study received a score of 1/9 = 0.11. It has been assumed that each study included all relevant ES; those ES not ranked in a particular study therefore received a score of zero for that study.

[19] There is little consensus on cultural ES definitions (Dickinson and Hobbs, 2017), so this review has attempted to group similarly described ES together. For example, references to biodiversity and providing habitat for wildlife have been merged as a single cultural service (representing the intrinsic value of species), distinct from the cultural ES of nature connections (representing the instrumental value of species).

Table 2.1: Order of preference for the ecosystem services mentioned/ranked by the 22 papers

Rank	ES (or benefit)	Frequency/22	Rank	ES (or benefit)[a]	Score/22
1	Heat amelioration [a]	18	1	Aesthetic beauty [b]	13.21
=2	Aesthetic beauty [b]	15	2	Heat amelioration [a]	12.11
=2	Habitat for wildlife [b]	15	3	Air purification [a]	9.43
4	Air purification [a]	14	4	Habitat for wildlife [b]	9.34
5	↑ property value [b]	13	5	Recreation opportunity [b]	7.01
6	Recreation opportunity [b]	12	6	Sense of tranquillity [b]	6.29
=7	Carbon sequestration [a]	11	7	↑ property value [b]	5.68
=7	Noise reduction [a]	11	8	Carbon sequestration [a]	5.61
9	Stormwater attenuation [a]	10	9	Nature connections [b]	5.44
10	Nature connections [b]	9	=10	Stormwater attenuation [a]	4.56
=11	Sense of tranquillity [b]	8	=10	Water purification [a]	4.56
=11	Sense of community [b]	8	12	Noise reduction [a]	3.84
13	Wind control [a]	7	13	Sense of history [b]	3.43
=14	Water purification [a]	6	14	↑ health/wellbeing [b]	2.91
=14	Sense of history [b]	6	15	Sense of community [b]	2.39
=16	Education opportunity [b]	4	16	Education opportunity [b]	2.35
=16	Inspiration/spirituality [b]	4	17	Wind control [a]	2.27
=16	↑ health/wellbeing [b]	4	18	Inspiration/spirituality [b]	1.81
=19	Fuel provision [c]	3	19	Other cultural ES [e]	1.76
=19	Other cultural ES [e]	3	20	Food provision [c]	1.21
=21	↑ business revenue [b]	2	21	Urban enhancement [b]	0.88
=21	Food provision [c]	2	22	Water provision [c]	0.53
=21	Soil stabilisation [a]	2	23	↑ business revenue [b]	0.48
=21	Timber provision [c]	2	=24	Soil stabilisation [a]	0.39
=21	Urban enhancement [b]	2	=24	Fuel provision [c]	0.39
=21	Water provision [c]	2	26	Other regulating ES [d]	0.25
=27	Other provisioning ES [f]	1	27	Timber provision [c]	0.24
=27	Other regulating ES [d]	1	28	Other provisioning ES [f]	0.17

[a] Regulating ES/benefit
[b] Cultural ES/benefit
[c] Provisioning ES/benefit
[d] Other regulating ES: Disease/pest regulation (mentioned by one paper)
[e] Other cultural ES: Road safety; Sense of family; Future generations (each mentioned by one paper)
[f] Other provisioning ES: Raw materials/genetic resources (mentioned by one paper)

Table 2.1 reveals that, in general, the ES that are most often included in citizen preference studies (heat amelioration, aesthetic beauty, habitat for wildlife, and air purification), are also the ones that are most preferred. However, this pattern was not always evident; for example, noise reduction was often mentioned, but usually considered of low importance. Aesthetic beauty was frequently considered to be respondents' preferred urban forest ES (being ranked first in eight out of the 15 studies in which it received a ranking). It therefore receives the highest score of all of the ES, despite only being in the top three ES mentioned in the papers. Overall, cultural services were mentioned 105 times across the 22 papers, with an average score of 0.60 (out of a

maximum of 1); this makes them the preferred ES category amongst the studies' respondents. Regulating services were also frequently mentioned (80 times), but had a lower average score of 0.54. Provisioning services were the least preferred ES category amongst the respondents of these studies, mentioned 10 times with an average score of just 0.25 – however this is not surprising given the urban focus of the studies.

Thirteen of these 22 papers additionally mention and rank negative attitudes towards the disservices provided by urban trees.[20] Overall, disservices were considered to be much less important than ES. For example, Lohr *et al.* (2004) found that residents of the United States' largest cities agreed or strongly agreed with the list of 'reasons to have trees in cities', whilst they disagreed or strongly disagreed with the list of 'problems with trees in cities'. Similarly, Schroeder *et al.* (2006) found that respondents in the United States considered all tree disservices to be of less than minor importance, compared to ES which were all considered to be of minor to moderate importance. However the same authors found that respondents in the UK placed leaf fall (a minor-moderate nuisance), and root damage to property, tree sap, the blocking of sunlight, and the blocking of views (all minor nuisances) to be more important than the benefit of shade provision (Schroeder *et al.*, 2006). In the more recent study by Graça *et al.* (2018), of 14 benefits and 8 costs related to street trees in Portugal, only one disservice (allergies) was rated higher than two of the ES (increased business revenue and property value).

The following table (Table 2.2) shows the number of papers that mentioned a particular disservice (frequency/13), and the average ranking that each disservice received compared to the other disservices in the same study (score/13). This analysis shows that the greatest concerns people have regarding urban forests is the damage that tree roots and canopies can cause to infrastructure (primarily pavements, overhead power lines, drains and sewers), and the damage that falling trees and branches can cause to people and property. The financial cost of managing trees was also a common complaint, though Lohr *et al.* (2004) pointed out that reducing spending on tree maintenance would be likely to adversely affect future provision of disservices and ES.

[20] It is not clear why the other nine papers did not consider disservices; this perhaps reflects the research and publication bias towards ES instead of disservices.

Table 2.2: Order of dissatisfaction for the disservices mentioned/ranked by the 13 papers

Rank	Disservice	Frequency/13	Rank	Disservice	Score/13
1	Damage to infrastructure	9	1	Damage to infrastructure	6.73
=2	Fear/ security concerns	7	2	Tree/ branch fall	5.37
=2	Leaf fall	7	3	Allergies	3.87
=2	Tree/ branch fall	7	4	Cost	3.73
=2	Ugly/ spoils view	7	5	Leaf fall	3.45
=6	Blocks light/sun	6	6	Fear/ security concerns	3.40
=6	Cost	6	7	Blocks light/ sun	2.93
=8	Allergies	5	8	Ugly/ spoils view	2.64
=8	Pests/ diseases/ invasives	5	9	Takes up too much space	2.53
10	Takes up too much space	4	10	Causes drainage problems	2.00
11	Restricts driver visibility	3	11	Pests/ diseases/ invasives	1.99
=12	Too time-consuming	2	12	Restricts driver visibility	1.73
=12	Causes drainage problems	2	13	Too time-consuming	1.17
=12	↓ land/ property value	2	14	Tree sap	1.03
=12	Tree sap	2	15	Blocks business signs	0.86
=16	Uses up too much water	1	16	↓ land/ property value	0.79
=16	Blocks business signs	1	17	Uses up too much water	0.30

Differences in preferences for ES (and disservices) may be connected with socio-demographic factors. For example, authors such as Hubacek and Kronenberg (2013), Dobbs *et al.* (2014), and Li and Liu (2016) have suggested that wealthy people tend to be exposed to a greater provision of ES than disadvantaged people, and so are more likely to value them. However, just seven of the 22 reviewed papers reported on the relationship between socio-demographics and ES preferences. The four papers linking income or education with ES had partially conflicting results, whilst relationships with age and gender are even less apparent. For example, whilst Derkzen *et al.* (2017) and Kirkpatrick *et al.* (2012) found wealthier, older and/or more educated people to prefer regulating ES, Tran *et al.* (2017) found regulating ES to be preferred by poorer, younger and less educated people. Meanwhile, Graça *et al.* (2018) found regulating ES to be preferred by more educated people (and to a lesser extent women), but there was no relationship with age or income. Due to the inconclusive findings from this small sample, it is not possible to associate preferences for particular ES with specific groups of people.

Different preferences for ES could also be affected by perceptions of climate. For example, Tran *et al.* (2017) found respondents concerned about climate change had a greater preference for regulating ES than those without such concerns. In almost every study that rated both heat amelioration and stormwater attenuation, the former was more strongly preferred. Lo *et al.* (2017) suggested this may be because heat amelioration has a more direct impact on citizens' comfort and wellbeing than stormwater attenuation. However, with climate change likely to increase the number of people affected by flooding, this ES may become more important to

citizens in future. For example, Derkzen *et al.* (2017) found that respondents in the Netherlands were more aware of present-day heatwaves than floods, but more concerned by future flooding than future heatwaves. Furthermore, the ES of heat amelioration was ranked significantly higher in studies conducted with citizens residing in countries with warm to hot summers, than in those with cool to mild summers.[21] Indeed, for the 11 studies conducted in warm climates, heat amelioration is ranked 1st out of 28 ES (with an average score of 0.78 out of 1); whilst for the 11 cool studies, it ranks only 4th (with an average score of 0.53).[22]

A number of other ES also ranked noticeably differently between these two climatic groups, more likely reflecting their differences in geography and culture (i.e. Europe vs. the United States). For example, recreation and nature connections were ranked much higher in the cool/European studies (3rd vs. 10th and 6th vs. 12th respectively). In contrast, noise reduction and water purification were ranked much higher in the warm/US studies (8th vs. 16th and 5th vs. 19th respectively). T-tests confirmed that regulating ES are, on average, considered significantly more valuable by citizens in the United States/warm countries,[23] and cultural ES significantly more so in European/cool countries.[24]

2.3.2 People's contributions to nature – who will pay for what, and why?

The studies reviewed in the preceding sub-section reveal that citizens hold preferences for a range of urban forest ES. But do they consider these services sufficiently valuable to pay to maintain/increase their provision, and if so, how much? Furthermore, what factors drive people's willingness-to-pay (WTP) for the provision of urban forest ES? This sub-section reviews 20 stated preference studies that have used either contingent valuation (CV; n=13) or a discrete choice experiment (DCE; n=7) to determine people's WTP for urban forests.[25] Once again, only studies from temperate, developed cities (i.e. potentially similar to Southampton) were used; in this case

[21] The cool studies comprise all those in Europe (n=9), plus New Zealand and one of the Canadian studies; whilst the warm studies comprise those undertaken in the United States (n=8), plus Australia, China and the other Canadian study.

[22] The average heat amelioration scores from the nine 'warm' and eight 'cool' studies that mentioned it were compared using a t-test. This confirmed a significant difference ($v = 12$, $t = 1.909$, $p = 0.040$), with the warmer studies having higher mean scores. There were exceptions to the rule though; heat amelioration was ranked 2nd highest out of six ES in Manchester, UK, but only 4th out of five ES in Fuzhou, China (Mell *et al.*, 2013; Chen and Qi, 2018).

[23] Regulating ES scored an average of 0.48 (out of 1) in the cool/European studies and 0.60 in the warm/American ones – significantly higher for the latter ($v = 78$, $t = 1.908$, $p = 0.030$).

[24] Cultural ES scored an average of 0.64 (out of 1) in the cool/European studies and 0.55 in the warm/American ones – significantly higher for the former ($v = 98$, $t = -1.861$, $p = 0.033$).

[25] The CV method involves asking respondents directly how much they are willing to pay in exchange for a marginal improvement to a non-market good, e.g. the urban forest as a whole (Pearce *et al.*, 2002). In contrast, a DCE ascertains WTP indirectly for specific 'attributes' of that good (e.g. woodland facilities, tree species, ES, etc), by asking respondents to choose their preferred combinations of attributes (one of which being 'price') from multiple different alternative options.

from Europe (n=11), North America (n=4), Asia (n=4), and Australasia (n=1). Thirteen studies obtained their data via household surveys (online, by post, or face-to-face), whilst seven conducted face-to-face interviews in public spaces such as streets or parks.

Though the purpose of this review was to determine citizen WTP for the provision of urban forest ES, only two of the 20 studies explicitly valued individual ES.[26] Morawetz and Koemle (2017) was the first, using CV to value heat amelioration by asking respondents how much they would be willing to pay for additional street trees to help combat the urban heat island effect. Soto *et al.* (2018) then used a DCE to ascertain WTP for a regulating ES (shade provision), a cultural ES (increased property prices), and avoidance of a disservice (structural damage) provided by neighbourhood trees. Instead, the main focus of the reviewed studies was to ascertain WTP for changes to the wider urban forest, including protecting/planting street trees (n=9), protecting/enhancing/creating urban woodlands/parks (n=7),[27] and protecting/increasing urban forest cover more generally (n=5). Despite this, the majority of papers did describe the ES likely to be provided by their proposed changes to the urban forest, though it is not always clear whether these ES were explicitly mentioned to the respondents. The ES described in the papers are set out by type of urban forest change in Figure 2.1 below.

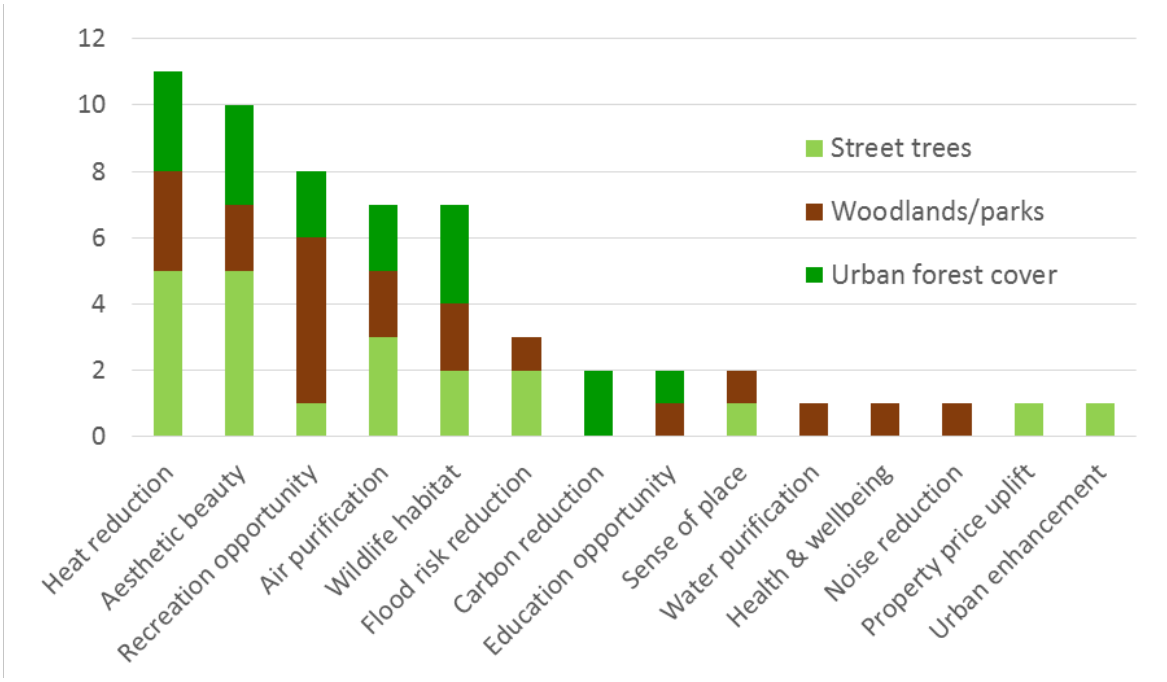


Figure 2.1: Number of reviewed papers (indirectly) valuing urban forest ecosystem services

[26] This is surprising, as valuing specific ES is common in stated preference studies on *rural* forests (e.g. see Brey *et al.*, 2007; Gatto *et al.*, 2014; Kragt *et al.*, 2016; Roesch-McNally and Rabotyagov, 2016; Aguilar *et al.*, 2018).

[27] One study sought respondents' WTP for the establishment of green infrastructure more broadly; this comprised both street trees *and* wooded parks (as well as grass verges, canals, playgrounds, green roofs etc), so has been included in two of these categories (Derkzen *et al.*, 2017).

The studies' average annual WTP values per respondent/household for the various changes to the urban forest (in GPB in 2018 prices)[28] are as follows:

- Planting new street trees: £26 (Mell et al., 2013), £52 (Morawetz and Koemle, 2017), £94 (Soto et al., 2018), £102 (Giergiczny and Kronenberg, 2014), £341 (Ng et al., 2015);
- Creating new urban woodland or parks: £28 (Andrews et al., 2017), £45 (Chen and Jim, 2008), £71 (Tu et al., 2016);
- Creating new GI, including street trees and urban woodland and parks: £10 (Derkzen et al., 2017);
- Increasing urban forest cover: £58 (Vecchiato and Tempesta, 2013), £62 (Tran et al., 2017), £69 (Upton et al., 2012);
- Protecting existing urban forest cover: £8 (Lorenzo et al., 2000), £93 (Vesely, 2007);
- Protecting existing street trees: £86 (Jetter and Paine, 2004), £136 (Mell et al., 2016), £157 (Lo and Jim, 2015);
- Protecting/improving an existing urban woodland: £7 (Japelj et al., 2016), £28 (Tyrväinen, 2001).[29]

The WTP values of course depend on the change being proposed for the specific urban forest feature and the context of the study, so are not directly comparable. Furthermore, the sample is small. Nevertheless, with these caveats, t-tests have been run to identify patterns regarding WTP in these studies:

- WTP for creating new urban forests is no higher than for protecting existing ones ($v = 16$, $t = 0.182$, $p = 0.858$);
- WTP for street trees is higher than for urban parks and woodlands ($v = 9$, $t = 2.344$, $p = 0.044$);
- WTP via tax is no lower than via any other mode of payment ($v = 17$, $t = -0.201$, $p = 0.843$);
- WTP via monthly payments is higher than via annual payments ($v = 8$, $t = 2.162$, $p = 0.031$);
- WTP is slightly lower in European studies than those from Asia/Australasia/North America, but not significantly so ($v = 9$, $t = -1.501$, $p = 0.084$).

[28] These were converted from their original currencies for the years in which each survey was undertaken into 2018 GBP by: 1) using purchasing power parity data (OECD.Stat, 2019) to convert currencies into US $ for the year of survey; 2) converting the latter into 2018 US $ using the US consumer price index (InflationData.com, 2019); and 3) converting these into GBP using the average exchange rate for 2018 of 0.75000.

[29] In the study by Chen and Qi (2018), respondents were willing to pay an entrance fee of £1.25 per visit to the urban forest park, in return for improved maintenance of trees and recreational facilities. Unfortunately, the annual number of visits per respondent was not provided, so it has not been possible to calculate the average annual WTP value.

In terms of who in society is most likely to contribute financially to urban forest ES delivery, and why, the studies revealed that wealthy, highly educated, young and/or male respondents were generally willing to pay the most. The most influential factor was income, with eight studies finding a significant positive relationship with WTP. However, two studies (Japelj *et al.*, 2016; Tu *et al.*, 2016) found lower WTP amongst wealthier respondents. Age was found to have a significant negative relationship with WTP in seven studies; however Mell *et al.* (2013) found the opposite, whilst two studies found WTP highest amongst mid-aged groups (Lorenzo *et al.*, 2000; Morawetz and Koemle, 2017). Five studies found a significant positive relationship between WTP and level of education, but Mell *et al.* (2016) had the opposite result. Finally, three studies found significantly higher WTP amongst men (Mell *et al.*, 2016; Morawetz and Koemle, 2017; Chen and Qi, 2018). Ethnicity and home ownership were generally found to be unrelated to WTP.

A number of studies have suggested that people's underlying values, beliefs, attitudes, and norms may influence their WTP for environmental programmes – possibly to a greater extent than their socio-demographic characteristics (e.g. Stern *et al.*, 1999; Muradian *et al.*, 2010; Klöckner, 2013; Obeng and Aguilar, 2018). Stated preference surveys often ask questions about people's environmental attitudes and behaviours, and use these as explanatory variables in determining WTP (an early example is Luzar and Cosse, 1998). However, the 20 studies reviewed in this sub-section placed little emphasis on linking WTP with respondent attitudes, beyond the importance they assign to urban forest ES (mentioned by 13 studies). The ES found to be most influential on respondents' WTP were aesthetic beauty (mentioned by six studies), recreation (n=5), habitat for wildlife (n=4), air purification (n=3), and heat amelioration (n=3).

Other attitudinal data captured through the studies and linked to WTP included opinions on climate change (mentioned in two studies), perceptions on the prevalence of trees and other GI in the study area (n=5), and whether or not people use the valued urban forest resource (n=7). Regarding people's level of understanding and concern about extreme weather events, Tran *et al.* (2017) found a positive relationship with WTP, but Derkzen *et al.* (2017) found no relationship. There was greater consensus regarding whether people living in areas with many or with few trees are willing to pay more for urban forest enhancement, with four studies supporting the latter (Chen and Jim, 2008; Giergiczny and Kronenberg, 2014; Derkzen *et al.*, 2017; Morawetz and Koemle, 2017). However, Tran *et al.* (2017) found a positive relationship between WTP and existing tree canopy cover, which they suggested was because these residents "more readily understand the benefits of the trees" (p.90). Finally, users of urban woodlands and parks were willing to pay more for urban forest enhancement than non-users in three studies (Tyrväinen, 2001; Tu *et al.*, 2016; Andrews *et al.*, 2017), whilst four studies found no relationship. Whether

respondents were driven by individual or shared instrumental values, intrinsic values, or relational values, was not discussed in these papers.

Sixteen of the 20 studies also reported that some respondents are not willing to pay anything for urban forest enhancement. On average, 24% of respondents were unwilling to pay, though this figure varied substantially across studies, from 1% (Upton *et al.*, 2012) to 52% (Chen and Qi, 2018). The studies and wider literature (e.g. Halstead *et al.*, 2017) suggest two main drivers for unwillingness to pay:

a) 'Protesters' object to the principle of paying, and were identified in 15 of the reviewed papers. These people refused to pay because they object to paying for/monetising nature (n=10); they think someone else (e.g. the local council) should pay (n=7); they don't believe the scheme will work due to a distrust of government or free riders (n=4); or they find it unfair that they should have to pay (n=5).
b) 'Legitimate zero bidders' generally lack interest in the proposed scheme, and were also identified in 15 of the papers. These people refused to pay because they consider enhancement of the urban forest to be unnecessary or unimportant (n=9); they can't afford to pay (n=7); they don't believe the scheme will achieve its aim due to inferiority of nature-based solutions compared to grey infrastructure or policy-based measures (n=6); or they need more information (n=4).

In order to address the issue of protesters, two studies investigated whether respondents would support the proposed urban forest enhancements by means other than (direct) payments. Vesely (2007) found that 55% of respondents who refused to pay would be willing to help protect city trees with four hours of voluntary work per year (compared to 70% of those who would pay). Later, Mell *et al.* (2013) asked respondents who were unwilling to pay extra council tax for street tree planting, how much of their *existing* council tax they would be willing to allocate (thus reducing funding for other council services). Though average WTP via this means was positive, it was significantly lower than the average direct WTP value. Mell *et al.* (2013) suggest this may be due to this group having lower interest in GI (protesters and legitimate zero bidders were not distinguished in this study).

2.3.3 Impact of ecosystem services delivery uncertainty on citizen willingness-to-pay

As discussed in sub-section 1.1.7, the complexity of socio-environmental relationships, insufficient scientific knowledge about these, and the occurrence of stochastic events, means that the outcomes of environmental enhancement programmes cannot be (accurately) quantified, reflecting 'Knightian uncertainty' (Knight, 1921). A number of studies have called for this

uncertainty to be taken into account in environmental decision-making, as failing to do this omits an important aspect of policy design, biases results, and can cause people to reduce support for policies they don't trust (Wielgus *et al.*, 2009; Glenk *et al.*, 2014; Lundhede *et al.*, 2015; Moffat, 2016; Ashley *et al.*, 2018). As a result, stated preference studies are increasingly incorporating outcome uncertainty[30] into their scenarios and choice questions, in order to identify whether, and to what extent, it affects people's WTP for environmental programmes.

None of the stated preference studies on urban forests reviewed in the previous sub-section have addressed the issue of outcome uncertainty. The 20 stated preference studies reviewed in *this* sub-section (19 DCEs and one CV study) therefore investigate uncertainty of environmental outcomes more broadly, covering a range of different habitats and issues. The studies reviewed here have ascertained the impact of environmental outcome uncertainty on citizen WTP in a variety of different ways, suggesting little consensus on the best approach:[31]

- Including a separate uncertainty attribute with varying levels (n=9);
- Incorporating uncertainty (in the form of single/multiple probabilities or a range) directly into the environmental attribute (n=7);
- Varying uncertainty only across rather than within choice tasks, using one of the above techniques (n=4);
- Incorporating uncertainty only into the scenario (n=1); and
- Providing no 'objective' information on uncertainty, but asking respondents for their 'subjective' beliefs about the likelihood of the environmental outcome (n=1).

To whom information on uncertainty is provided – or obtained *from*, in the case of the CV study by Adhikari *et al.* (2017) – also varies between studies. Thirteen opted for all respondents; two adopted a before-after approach by introducing uncertainty halfway through the choice tasks; and seven split respondents into sub-samples whereby the control group received no uncertainty information, but one or more treatment groups did.

The overwhelming conclusion (made in 15 of the 20 papers) is that respondents are more likely to pay, and/or willing to pay more, for environmental policies and programmes the more certain are the outcomes. For example, for each 1% increase in the probability of policy success, respondents were willing to pay an additional A$3.6 per month for a climate change mitigation scheme to

[30] This is typically framed as 'probabilistic uncertainty' (i.e. a quantified risk) rather than Knightian uncertainty. This is because the vagueness of the latter may make it difficult for respondents to make their choices, whilst they will also interpret this uncertainty in different ways (e.g. optimistically or pessimistically), which reduces the researcher's ability to explain respondent choices (Louviere *et al.*, 2000; Jakus and Shaw, 2003; Wielgus *et al.*, 2009).

[31] Two studies (Roberts *et al.*, 2008; Wielgus *et al.*, 2009) used more than one technique. See sub-section 5.2.3 for detail on the design of DCEs, incorporating scenarios, choice tasks, attributes and levels.

combat temperature rise (Akter *et al.*, 2012); an additional £1.67 per year for a climate change mitigation programme to sequester carbon (Glenk and Colombo, 2011); and an additional A$7.42-10.39 per year for management options to improve the proportion of the Great Barrier Reef in good condition (Rolfe and Windle, 2010). In some cases, WTP for environmental policies and programmes was considerably higher when presented with certain outcomes than with uncertain outcomes, for example, Wielgus *et al.* (2009) found both anglers and scuba divers willing to pay twice as much for conservation resulting in more/larger fish when this was guaranteed.

Of the remaining five studies, one found no statistical difference in WTP for certain vs. uncertain outcomes (Veronesi *et al.*, 2014); one found mixed results depending on the level of the proposed benefits (Shrestha and Alavalapati, 2004); and three studies found WTP values to be significantly higher for the *uncertain* outcomes than the certain ones. For example, Roberts *et al.* (2008) found WTP for removal of algae from a recreational lake to be more than three times higher when occurrence of algal blooms was uncertain, whilst WTP for increased water levels was also higher under the uncertain treatment. The authors suggested this may be due to the general public finding even a small risk of an algal bloom to be unacceptable. Similarly, respondents in the study by Faccioli *et al.* (2018) were willing to pay more than twice as much for an uncertain increase in wetland bird species of 4-6 than for an equivalent certain one of 5. A related study by Torres *et al.* (2017) revealed that WTP for conservation for a unit increase in the expected no. of bird species was half as much for 100% certainty compared to 80% or 60% certainty. The authors suggested this may be due to respondents adopting a precautionary approach, i.e. thinking it is better to act even when outcomes are uncertain than to do nothing.

Some authors have suggested that incorporating objective uncertainty information in DCEs can make scenarios appear more credible and/or realistic, and as such may *increase* WTP (Burghart *et al.*, 2007; Roberts *et al.*, 2008; Wielgus *et al.*, 2009; Glenk and Colombo, 2011). Unfortunately, none of these, or any other studies, have specifically tested this hypothesis.[32] To do so, a study would need to determine people's prior perceptions (i.e. their subjective beliefs) about the likely success of an environmental programme, and then ascertain what effect this has on how people respond to objective uncertainty information.

Only three of the reviewed studies investigated people's prior perceptions of the likely success of environmental programmes (Akter *et al.*, 2012; Lundhede *et al.*, 2015; Adhikari *et al.*, 2017). Each

[32] Wielgus *et al.* (2009) made the suggestion after finding better goodness-of-fit for their choice model with 90% certainty than for the model with implied full certainty, whilst Glenk and Colombo (2011) suggested it after finding the variance of the error term of utility to be *smaller* when the risk attribute was included. However, as the latter study used a before-after treatment design, Glenk and Colombo (2011) admitted that learning effects could also have caused the smaller variance.

of these found subjective beliefs to be important determinants of WTP, with those who doubt the effectiveness of a scheme willing to pay significantly less (or being less likely to pay) than those who trust the scheme will be successful. However, only Lundhede *et al.* (2015) investigated whether people's prior beliefs affect how they react to the provision of objective uncertainty information. By interacting a prior belief variable with the (objective) uncertainty variable in their choice model[33] (in addition to including the latter variable on its own), Lundhede *et al.* (2015) were able to show that the negative effect of objective uncertainty on WTP is significantly reduced for respondents who a priori trust that the proposed environmental outcomes will occur. In other words, a priori trusters are less averse to objective uncertainty information than a priori doubters. However, Lundhede *et al.* (2015) did not explicitly investigate whether such information improves the realism/credibility of a scheme. This would have required further modelling (incorporating a prior belief-only variable) to ascertain how trusters and doubters each react to certain and uncertain outcomes.

Festinger (1957) stated that being faced with contradictory information (e.g. certain outcomes being presented to a doubter, or uncertain ones to a truster) causes people mental stress and discomfort, known as cognitive dissonance. To avoid this, people will either change their attitudes to make them consistent, or will devalue/discard the conflicting piece of information (Festinger, 1957; Hirschman, 1965; Akerlof and Dickens, 1982). Studies in psychology, marketing and health have found that prior beliefs tend to be prioritised over conflicting objective information in decision-making (e.g. Lord *et al.*, 1979; Kardash and Scholes, 1996; Taber and Lodge, 2006; Huffman *et al.*, 2007; Delavande, 2008). In the context of a PES scheme with uncertain outcomes, such research suggests that a priori trusters may be content to pay even when outcome uncertainty is revealed, whilst doubters will reject a scheme that implies outcomes are certain to occur. Obtaining posterior beliefs about outcome uncertainty and/or scheme credibility would therefore also be useful for identifying how a priori trusters – and particularly a priori doubters – each react to objective uncertainty information.

2.3.4 Conclusion and implications for the thesis

This final section of the literature review has provided insights into the extent to which regulating and other ES provided by urban forests are valued by citizens, and has attempted to show whether citizens are willing to invest in their enhancement. Based on a review of 22 studies, section 2.3.1 showed that aesthetic beauty is by far the preferred urban forest ES, followed by

[33] See sub-section 5.2.2 for detail on choice modelling.

heat amelioration, air purification, habitat for wildlife, recreation opportunities, and a sense of tranquillity. The 20 studies reviewed in sub-section 2.3.2 revealed that most respondents are willing to pay for urban forest enhancements associated with provision of a bundle of these services, however, there is a gap in the stated preference literature regarding WTP for delivery of *individual* urban forest ES. Wealthy, highly educated, and young respondents typically had higher WTP than other socio-demographic groups, but attitudinal drivers of WTP were investigated by too few studies to draw conclusions. Finally, the review also revealed that in most cases, respondents are willing to pay less (and/or are less likely to pay) for environmental schemes when their outcomes are presented as uncertain rather than certain. However, few studies have ascertained whether respondents have prior doubts about the likely success of environmental programmes; and none have established whether admitting ES uncertainty will increase or decrease public support for environmental programmes.

This review has served to guide the development and delivery of Objective 3 of the thesis, which seeks to fill the gap in knowledge of whether, why, and to what extent citizens might be willing to pay for specific regulating ES provided by urban forests (using the UK city of Southampton as a case study). The cultural service of aesthetic enhancement is also included in the Objective 3 DCE, given the importance citizens have placed on this ES in the reviewed studies. Due to identified gaps in the literature, and the relevance to setting up a PES scheme to fund specific yet uncertain ES outcomes, Objective 3 will also seek to identify the effect of combined objective and subjective uncertainty on citizen WTP for individual ES, and an urban forest PES scheme as a whole.

Chapter 3 Challenges for tree officers to enhance the provision of regulating ecosystem services from urban forests

A version of this chapter was published in the journal *Environmental Research* in July 2017 as Davies *et al.* (2017b). The paper was written solely by the researcher; her supervisors (the co-authors) provided comments on several drafts.

3.1 Introduction

Urbanisation (particularly densification) is increasing the risk of flooding (Eigenbrod *et al.*, 2011) and extreme heat episodes (Lemonsu *et al.*, 2015) in Europe's cities due to the loss of urban greenspace (Davies *et al.*, 2011). Air pollution is also a problem in many densely populated cities, particularly in more deprived areas (Netcen, 2006), and is forecast to be an increasing public health concern as the climate warms (De Sario *et al.*, 2013).

Concern about the impacts of climate change on urban environments has led to a growing interest in nature-based solutions, which can pose an effective solution to some of the negative impacts of urbanisation (Andersson *et al.*, 2014; European Commission, 2015). Within urban areas, regulating ES are provided predominantly by the urban forest (Davies *et al.*, 2017a). This is because, in comparison with other forms of green infrastructure, trees and woodlands are particularly effective at alleviating summer heat through evaporation, photosynthesis and shading (Doick and Hutchings, 2013); reducing stormwater run-off by intercepting and absorbing water and improving infiltration (Armson *et al.*, 2013); and enhancing air quality by intercepting and/or absorbing gaseous pollutants and particulate matter (Escobedo and Nowak, 2009).

The urban forest can also have adverse effects on society. Some of the most frequently reported disservices provided by urban forests are increased ground-level ozone through the emission of biogenic volatile organic compounds, the blocking of light and heat, tree root-induced damage to infrastructure, a risk of injury or damage from tree or branch fall, and pollen-associated allergic reactions (Roy *et al.*, 2012). Trade-offs between the ES provided by urban forests can also occur, particularly between regulating and cultural services, leading to a reduction in expected benefits (Bennett *et al.*, 2009; Davies *et al.*, 2017a). Handley and Gill (2009) suggest that for urban forests to better help urban society, it is necessary to address the information gap on the nature and

extent of each local authority's urban forest, and to conduct further research on decision support systems which improve understanding of ES and associated economic benefits.

Matthews *et al.* (2015) suggest there has now been sufficient literature published on the biophysical capacity of green infrastructure to help cities adapt to climate change. However, Guerry *et al.* (2015) and Ojea (2015) have found that uncertainties around ES delivery and the link with wellbeing, as well as measurements of these, are still preventing ES information from fundamentally changing decision-making across the world – known as 'information failure'. Poor understanding of socio-political factors (including governance, funding and public involvement) is also preventing information on nature-based solutions being acted upon by local government decision-makers – known as 'institutional failure' (Turner and Daily, 2008; Matthews *et al.*, 2015). For example, Ojea (2015) identified issues of poor governance structures, limited public participation, and inappropriate financial mechanisms. Similarly, Guerry *et al.* (2015) found governments, businesses and civil society are not working together closely enough to ensure that ES are integrated into every day decision-making.

Studies have further identified problems relating to short-term decision-making failing to deal with the long-term nature of climate change and environmental processes, as well as concerns about free-riders – known as 'market failure' (Turner and Daily, 2008; Guerry *et al.*, 2015; Ojea, 2015). Finally, 'path dependence', whereby local authority decision-makers favour fixed patterns of thinking and lack motivation to respond meaningfully to new problems and solutions, is identified as a significant constraint to embracing green infrastructure in the UK and Europe (Matthews *et al.*, 2015). For example, Naumann *et al.* (2011) found 'habitual modes of practice' restricting the uptake of nature-based solutions to climate change adaptation in Europe. Wamsler (2015) suggests that such solutions to heat and flood risk are unlikely to be integrated into cross-departmental decision-making unless departments have previously worked together on other cross-cutting issues (such as climate change mitigation).

In terms of urban forest decision-making, Capotorti *et al.* (2016) suggest that regulating ES have been gaining increasing attention in Europe since publication of the EU green infrastructure strategy (European Commission, 2013), though whether this information has actually influenced action on the ground is unclear. Surveys of urban forest professionals in UK local authorities suggest that urban forest management is almost entirely reactive to human health and safety concerns (Britt and Johnston, 2008; Van der Jagt and Lawrence, 2015); ES delivery was not mentioned in these studies. In contrast, urban forest professionals in Canada and the United States regularly consider ES in their management activities (Young, 2013; Fontaine and Larson, 2016). Possible reasons for these diverging approaches have not been explored.

The purpose of this part of the thesis is to identify constraints and drivers to local authorities adopting an ES approach to urban forest management, using a case study of 15 UK cities. To this end, four research questions were posed:

1. What are the main objectives for urban forest management?
2. Do local authorities manage their urban forests for regulating ES and, if so, why and how?
3. What are the constraints to adopting proactive, ES-focused urban forest management?
4. How might local authorities adopt an ES approach going forwards?

3.2 Materials and methods

3.2.1 Data collection

Interviews were carried out with staff responsible for tree management decisions (referred to here as 'tree officers') in fifteen major local authorities from across Britain during April-May 2016. This represents a response rate of 54%, with 28 local authorities having initially been contacted (via email) based on their meeting the following selection criteria:

a) Unitary authorities or metropolitan districts, i.e. those responsible for all local government functions within their area under a single-tier administrative system. This ensures that the work of tree officers will not be influenced by other jurisdictions.
b) Classed as being urban – in England this includes authorities where at least 74% of the resident population lives in built-up settlements of at least 10,000 people (Defra, 2014b, 2016b), whilst for Scotland and Wales 'urban' refers to settlements of at least 3,000 and 10,000 people respectively (ONS, 2005; Scottish Government, 2014). This focuses the research on the areas most likely to be affected by the environmental problems of heat islands, surface water flooding, and air pollution.
c) A high population density to reflect the densification of urban areas being associated with environmental problems (this was set at a minimum of 25 persons per hectare).[34]

The interviews were semi-structured, with tree officers answering 32 open and closed questions that they were provided with in advance. Questions were grouped into five related categories, namely: the urban forest resource; approach to urban forest management; ES provided by the

[34] 30 persons per hectare was a more natural break in the data, however this was lowered to 25 in order to include Wales in the study – the population density of Cardiff is 25.2 persons per hectare.

urban forest; governance of the urban forest; and funding of the urban forest. These categories were chosen to identify firstly, whether there is still an information gap on the nature and extent of urban forests at local authority level (Handley and Gill, 2009). Secondly, whether UK urban forests are still managed reactively, or more proactively like in North America (Britt and Johnston, 2008; Young, 2013). Thirdly, if there is still an information failure within local government regarding delivery of ES benefits (Turner and Daily, 2008; Matthews *et al.*, 2015). And finally, whether citizens and businesses already contribute to their urban forests in some way (to support Objectives 2 and 3 of this thesis).

The full list of questions can be found in **Appendix B**. Prompts and follow-up questions were employed only if the tree officer's response was considered incomplete or unclear, or if they raised a point of particular relevance to the study (Foddy, 1993). Interviews were recorded and lasted for 54 minutes on average, ranging between 33 and 83 minutes. Where available, local authority policies relating to trees were analysed for specific mentions of ES.

Ethical approval for the interviews with tree officers was granted by Ethics and Research Governance Online (ERGO 19753) at the University of Southampton. Participating tree officers have been provided with linked anonymity, thus comments from individuals have been identified as 'TO1' up to 'TO15' rather than ascribing these to particular named local authorities.

3.2.2 Data analysis

The interview recordings were transcribed verbatim and edited to remove repetitions, stop words and habitual irrelevant phrases, whilst retaining accuracy. The transcripts were then analysed in the software package 'Nvivo v.10' (QSR International, 2012) using a thematic approach, following the process outlined by Braun and Clarke (2006). Thematic analysis is defined as "a method for identifying, analysing and reporting patterns (themes) within data", whilst "a theme captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set" (Braun and Clarke, 2006: 79 & 82). The process involved reading through each of the interviews in turn and coding extracts of text, making sure that all data relevant to a particular code was identified as such. This analysis was done across questions, as opposed to for each question individually, so that commonalities running through the data as a whole could be identified (Braun and Clarke, 2006). Codes were then collated into overarching themes, ensuring that they were sufficiently distinct from, yet related to, others within the theme. Initially an inductive approach was taken, allowing the data extracts themselves to suggest names for the themes and codes, rather than basing these on existing theories (Frith and Gleeson, 2004). However, due to the breadth of interview questions, it

was necessary to revise and reduce the number of themes and codes to ensure that only data contributing to answering the specific research questions addressed by this paper remained, with final themes both driving and being driven by the research questions (the latter also being influenced by the literature). A full list of themes, codes and their descriptions can be found in **Appendix B**. Direct quotations were then selected to illustrate the key points being made within each theme, as suggested by Braun and Clarke (2006).

Quantitative analysis was also performed where appropriate, and is presented in the form of frequencies and percentages. For example, in Tables 3.1 to 3.4, 'No. of refs' refers to the number of times the particular sub-theme (i.e. Nvivo code) appeared throughout the entire dataset, allowing comparison of code frequencies (Guest et al., 2012). In order to give an indication of the proportion of participants who addressed each sub-theme, the number and/or percentage of the 15 tree officers who commented on a particular topic at any point during the interviews is also provided in the tables, as well as elsewhere in the text (Toerien and Wilkinson, 2004). Whilst high frequencies or percentages are not necessarily a measure of significance (Toerien and Wilkinson, 2004), they offer an indication as to which concepts or situations experienced by tree officers are most commonly reported, and may therefore be expected to be shared amongst other tree officers.

Geographic, population and tree-related data (i.e. geographic location, geographic size, population size, population density, whether a tree strategy has been adopted, tree canopy cover,[35] and tree budget per head of population) were also collected for each of the interviewed local authorities. This was to enable identification of city characteristics that may have influenced the tree officers' responses with regards to particular themes. Local authorities were grouped into those strongly representing a theme, and those representing the opposite – based on the frequency with which they raised certain themes, and what they said on the subject (some authorities fell outside of these extremes and so were removed from further analysis). Detail on the process of the (non-statistical) analysis can be found in **Appendix B**.

3.3 Results

The interviews revealed many similarities but also some differences in tree officers' approaches to urban forest management and the constraints that act upon them. In general, responses seemed

[35] Information on tree canopy cover was obtained by the researcher using the software package i-Tree Canopy (USDA Forest Service, no date-a). The tool was used to identify tree cover at random points within each of the study cities using local authority boundaries and Google Maps aerial photography.

to be unrelated to the geographic, population and tree-related characteristics mentioned above, however some loose relationships were observed. The three cities identified as having proactive urban forest management were generally less (densely) populated and more likely to have tree strategies (either adopted or in development) than the reactive cities. The three cities considering regulating ES in their urban forest management were amongst the larger cities in the sample (in terms of area and population), with higher than average tree canopy cover and tree budgets. Interestingly, these three cities were also all in the group experiencing environmental issues. Finally, cities facing constraints to ES-focused management were less likely to have tree strategies and had lower budgets than those without such constraints. Additional results can be found in **Appendix B**.

3.3.1 Urban forest management focused on reducing risk and reacting to complaints

A high proportion (67%) of the tree officers interviewed indicated that they have a reactive approach to managing their urban forest (Table 3.1). Much of their time and financial resources are taken up by survey and maintenance activities to reduce the risk of trees causing injury to people or damage to property, and responding to complaints from the public about tree disservices. Addressing health and safety concerns was the dominant theme across the interviews – it was mentioned by all participants and a total of 65 times. All of the interviewed tree officers except TO9 indicated that they have received complaints about tree disservices (a total of 51 references). Undertaking management actions on a reactive basis was mentioned 35 times by all but TO9 and TO12.

When discussing the subject of 'complaints about disservices', tree officers generally did not mention specific disservices but referred to complaints and problems caused by trees, and reducing conflicts between people and trees. When specific disservices *were* mentioned, blocked sunlight came up as the most common disservice (13 references), followed by leaf fall (7), blocked TV signal (5), sap/honeydew falling onto cars (3), damage to buildings (3), creation of fear/anti-social behaviour (3), blocked views (2), blocked access to premises (2), damage to pavements (2), and bird droppings falling onto cars (2). Complaints about tree disservices are generally raised by citizens, with only a few tree officers reporting to have received complaints from businesses.

Table 3.1: Tree officer comments relating to taking a reactive approach to urban forest management

Sub-theme	No. of TOs	No. of refs	Example responses from local authority tree officers
Theme: Addressing health and safety concerns			
N/A	15	65	"We survey for health and safety, so that's the overriding policy as we have a duty of care to discharge, that's our primary reason. Obviously we need to look after our trees so that they don't hurt or damage anyone." (TO1) "[For] street trees particularly, it's more about risk – physical risk to property or people, or subsidence risk. And a lot of our street trees are managed to counter that. [For] park trees and woodlands, there's nowhere near the same level of focus." (TO12)
Theme: Complaints about tree disservices			
General complaints	12	36	"Citizens, our valued customers, don't seem to value trees at all most of the time… it's 'get rid of the trees cos they're just a nuisance to us as residents'." (TO8) "A lot of the trees that are still standing shouldn't be… they're not desirable, they're in the wrong place, they're doing the wrong thing, but we haven't got the money to get rid and we haven't got the money to replace." (TO11)
Specific disservices	10	16	"Businesses on the whole aren't as tree friendly I find, always wanting frontages clearing, signs unblocked, so trees are often seen as a nuisance to their business." (TO14) "For things like leaf litter, loss of light, shading, people want trees removed and they don't see the benefits of them." (TO4)
Influence on management	8	14	"Local elected members and the perceptions that they have… can be negative if they get a lot of people complaining about trees in a particular area; we could be under quite a lot of pressure to manage them more severely than we would (like)." (TO1) "People start to object to having a woodland on their boundary cos… it's quite a barrier to natural light – but also because of this problem of antisocial behaviour in them. So we often have to manage woodlands to create a zone so that they're not in contact with properties." (TO3)
Theme: Reactive approach to urban forest management			
N/A	13	35	"We're regularly and routinely carrying out visual tree inspections, but that tends to be on a tree-by-tree and location-by-location basis and also depends on the enquiries that come in… we're very much enquiry-led." (TO10) "There is a reactive, 'oh god that tree's just dropped a branch and we need to do something about it' kind of management." (TO8)

3.3.2 Managing urban forests for regulating ecosystem services

All interviewees were aware of the concept of ES, though to differing levels. When asked an open question about which ES they thought their urban forest was providing, 13 tree officers (87%) referred to specific regulating services; the other two (TO11 and TO12) only mentioned the aesthetic benefits that trees provide. Both TO11 and TO12 did however make a single reference to regulating ES at other points in the interviews: TO11 reported that both engineering work and trees should be used to address flooding; whilst TO12 recalled that a business had once contacted the council interested in planting trees to help offset their carbon emissions. Air purification and stormwater attenuation were quoted more often than heat amelioration. TO3, TO7 and TO13 in

particular suggested that heat amelioration was more relevant to warmer cities such as London or those in southern Europe. Overall, tree officers thought that the ES of most interest to their wider council was air purification, and to citizens and businesses, aesthetic enhancement (along with disservices; see Figure 3.1).

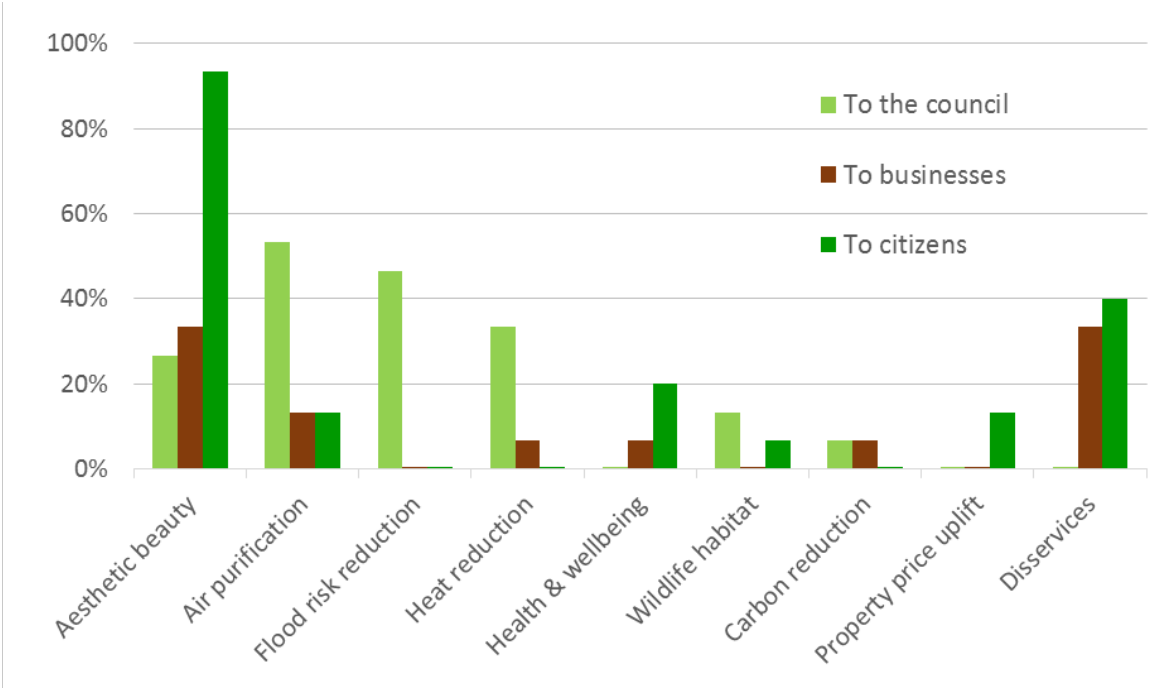


Figure 3.1: Proportion of tree officers who consider tree benefits to be important to their councils, businesses and citizens

When tree officers were asked to what extent their department takes an ES approach to urban forest management, seven (47%) stated that such an approach is not taken. Three (20%) said it is taken into account but is not a priority, whilst five (33%) said that is taken seriously within the tree team, but not across the wider council. However, when tree officers were asked how technical or scientific information is used to support urban forest planning and management, only one tree officer mentioned ES:

> *"We are keeping an eye scanning in terms of what research is out there and what relevance it has to us as a city, and then there's that more progressive research which is game changer stuff in terms of the ES stuff. So rather than it being just a tree issue, I'm quite interested in how we as a city might benefit from an ES based approach." (TO5)*

The interviews revealed few examples of tree officers actively managing their urban forests for any of the regulating ES. For example, TO1 suggested that whilst specific objectives to enhance air quality and stormwater attenuation supported urban forest retention, on a day-to-day basis their influence on tree management and maintenance was very limited. In contrast, TO5 had specific objectives to enhance air quality and stormwater attenuation and, in this case, providing these ES

dictated the choice of species and location (though this was a subjective decision as the benefits were not quantified):

> *"The first question we ask anybody when we're talking about trees is not 'what species do you want to plant and where do you want to plant it' but 'what outcomes do you wish to achieve from the tree that you wish to plant?' So you're looking to achieve, and from those benefits you can then play it back in terms of how the species and the orientation of the trees will then better provide those outcomes". (TO5)*

Two tree officers (TO5 and TO15) were using geographic information systems (GIS) to highlight spatial correlation between tree canopy cover and environmental issues such as flooding, air pollution, and heat island effects. TO5 had made use of this data in an attempt to influence local plan decision-making, whilst TO15 was using the data to support tree planting in certain locations. Finally, TO10 was using the results of an i-Tree Eco study to justify the benefits of trees when dealing with complaints from members of the public.

Of the fifteen local authorities investigated through this study, only four (27%) have adopted overarching tree strategies (published between 2002 and 2012). The tree officers said that ES are referred to in these strategies, however they did not provide any examples of how this influences tree management or enhances provision of these services. In the case of two strategies, published in 2002 and 2004, this is not surprising given that these predate much of the ES literature. Indeed, the strategy adopted in 2002 refers to tree benefits (including improved air quality and noise mitigation) only in its introduction. The 2004 strategy improves on this, containing a whole chapter on the environmental and social benefits of trees, however only visual amenity and wildlife conservation make it into the long list of strategy objectives.

One of the strategies, published in 2010, puts particular emphasis on the heat and flood regulation benefits of urban trees. For example, the strategy recommends large canopy species for addressing these problems and seeks to plant the right trees in the right places to maximise their effect. Finally, the 2012 strategy emphasises the contribution the city's trees make to the council's wider strategic priorities of quality of life and climate change adaptation and mitigation. It includes a chapter detailing all the benefits that urban trees provide, linking these with evidence on recommended species and tree and canopy sizes as well as some economic values of ES. Despite this, the strategy's nine-page action plan makes only three indirect references to ES, with "actively communicate the benefits of the urban forest to communities, colleagues and businesses" being of particular note.

Evidence of active tree management to enhance regulating ES in the study cities was rare. However, the interviews revealed that these qualities are certainly on the radar, fuelled by two main drivers. The first is the presence of environmental issues, such as flooding, in their cities and

an understanding by the tree officers that trees can help to alleviate such issues. This driver was mentioned 56 times in total and by all but one tree officer (TO12). The second driver was political support for trees and the benefits they provide (mentioned 43 times, and by all but TO13). Evidence from the interviews for both of these drivers is provided in Table 3.2.

Table 3.2: Tree officer comments relating to drivers for considering regulating ecosystem services in urban forest management

Sub-theme	No. of TOs	No. of refs	Example responses from local authority tree officers
Theme: Understanding of environmental issues			
Air pollution/ purification	13	40	"We're a major transit city for both international and national travel - so we've got attacks on all sides in terms of air quality. I do believe that local air quality can be significantly improved by local tree planting. All the scientific research seems to be pointing in that direction." (TO6) "We're most concerned about the absorption of pollution… If you can increase the volume of your tree cover you can increase the abatement of air pollution… It would be the size of the tree, the variety of tree. We know for example that London planes [Platanus × acerifolia] have a much better pollution abatement function than Pyrus chanticleer." (TO9)
Flooding/ stormwater attenuation	11	37	"We've particularly got issues in [the city] about flooding, and we now work very closely with the flood team… regarding flood alleviation schemes in our parks and that comes along with associated planting." (TO14) "There is flooding in certain areas of [the city] but there is no doubt that tree cover, both street trees and woodland, is increasing the time it takes for the rainfall to reach the water courses… If there is a flooding issue, we can plant trees that are much more efficient at transpiration… [such as] alder [Alnus sp.] and willow [Salix sp.]." (TO7)
Heat islands/ amelioration	10	23	"I would love to see more street trees go in to reduce the heat in the inner city... Trees casting shade and lowering the temperature would be fantastic." (TO8) "There's an industrial area along the [motorway] where there's a huge heat island… and that coincides with very few trees - so as new developments are going in there we're trying to encourage tree planting in those." (TO15)
Theme: Political support for trees			
Advocates in high places	9	18	"What we do every year is we will report what wasn't done, and on that basis we were actually told to spend more this year than last… We happened to have got a lot of political support and in a time of declining budgets that's quite unusual to be given additional money when other departments are losing resources." (TO3) "Our director of public health is an absolute fanatic about improving people's quality of life and [is] adamant about planting trees. So I've kind of got people in high places on my side." (TO8)
Adoption of tree strategy	6	11	"We make the case – the tree policy is there – we say this is what we're going to do, and the various departments need to put the money forward for that." (TO15) "Hopefully through pushing forward the strategy, (local air quality) will become a greater focus." (TO6)
General political support	7	9	"I know CABE Space were putting out information on trees, and the Landscape Institute has tried – some politicians have bought into that." (TO9)

Sub-theme	No. of TOs	No. of refs	Example responses from local authority tree officers
Supportive planning policy	5	6	"I think probably the biggest advantage is that we do have some clout through planning... That's our biggest lever for making sure we do get trees in the city." (TO1) "We have some very strong policies to deal with protecting trees. So the default is that trees shouldn't be removed unless there's a good reason, and if we do conclude that it is right to remove trees then we have a standard which requires up to 8 trees to replace any 1." (TO5)

3.3.3 Constraints to proactive, ecosystem services-focused management

There was widespread dissatisfaction amongst those interviewed with their reactive approach to urban forest management. Tree officers expressed a desire to move towards more proactive management, planned to enhance ES provision and reduce complaints. For example, one tree officer commented:

> *"We want to be much more aspirational. Obviously change people's minds about the value of trees and the multiple values and the benefits they can have as long as they're in the right place… (B)ut the disadvantage at the moment is… we're just maintaining a status quo, fire-fighting if you want to call it." (TO7)*

The tree officers were hopeful that the future would offer a greater focus on managing urban forests for regulating ES, but recognised that such a change would not be easy. NVivo analysis showed that constraints to moving towards an ES approach fell into four categories:

a) Funding constraints: 67% of interviewed tree officers said that their budgets had decreased, typically by 33-50%, in recent years;
b) Unsupportive governance structures: coordination and information-sharing between departments was a particular issue;
c) People not taking trees seriously: this was apparent both within the council and amongst citizens and businesses; and
d) Limited understanding of ES amongst stakeholders: relating to poor communication and education.

Each of these categories was raised by a majority of those interviewed – example responses are provided in Table 3.3.

Table 3.3: Tree officer comments relating to constraints to undertaking an ecosystem services approach

Sub-theme	No. of TOs	No. of refs	Example responses from local authority tree officers
Theme: Constraints to undertaking an ES approach			
Funding constraints	10	36	"There's a lot of politician speak about the benefits of trees… but quite often the money's only available for the actual capital and nothing's available for the revenue. So when these schemes come about they become a real drain to try and deliver." (TO11) "Well as a department we're very well aware [of ES] and we do and try and focus on it, but we're working against cuts in budgets and particularly our planting budget." (TO6) "I think we've unfortunately had to get more reactive because of the reduced budget." (TO14)
Unsupportive governance structures	9	21	"We're not working well enough with highways, with housing and planning to come up with a concerted joint effort on all of this… That probably goes from the fact that there's been a disjointed tree services department for the last 3 or 4 years and so no-one's been moving that agenda forward." (TO4) "There's a new (building) that's been built in the centre of town which has involved the removal of about 20 really nice healthy trees, but we weren't consulted on it at all." (TO13)
People not taking trees seriously	11	20	"We don't have a policy or a strategy at the moment… a cabinet member didn't like it – it was a bit too green for them unfortunately so it was never adopted… I think they think we're all a bunch of tree huggers here, and if we find out too much we're going to go around everywhere and put TPOs on all the trees." (TO13) "Some companies, I was trying to convince them to have tree planting around their development, and they were like 'we're going to have none of that because they'll encourage birds and birds will make a mess'. They wouldn't care about the other benefits." (TO15)
Limited understanding of ES amongst stakeholders	11	17	"I think [the council] probably would be interested in the air quality issues, but I don't think that link has been made strongly enough". (TO2) "I think we've got an education lack within the city; we don't sell the benefits of our trees to our citizens at all well at the moment." (TO4)

3.3.4 Promoting an ecosystem services approach

A number of suggestions were made by the interviewed tree officers about how they plan to address some of the constraints to taking an ES approach to urban forest planning and management going forwards (Table 3.4).

Table 3.4: Tree officer comments relating to how to adopt an ecosystem services approach to urban forest management

Sub-theme	No. of TOs	No. of refs	Example responses from local authority tree officers
Theme: Promoting an ES approach			
Awareness raising	13	31	"Until you've actually got facts and figures and scientific information to present to people, you can't just say, 'well we'd like trees because they're nice'… So this is why things like i-Tree are so valuable because it is starting to put a value that everybody understands – money – onto the services that trees are delivering. That changes the perception of them quite a lot." (TO1) "By putting a capital value on the ES they provide… that puts them [back] in the black." (TO15) "I've seen ideas in the States where they put a label on trees… [saying] 'this tree is worth £2,000', and then they itemise why it is worth £2,000. It really brings the value of that tree to people, and that potentially would act as a driver for business and people to sponsor the tree realising the tree value." (TO7)
Novel funding streams	11	23	"I think that anyone who lives, works or visits the city should in some way – even if it not be financial – should contribute. Particularly big industry… I would like to see them paying proportionately more because the impact they have is huge." (TO1) "There may be some arguments we can make which is that we are providing a benefit that is free and maybe it shouldn't be free going forward, and we should be trying to provide a payment system for that… We are thinking about creating a brokering system called something like a Natural Capital Trust." (TO5) "A lot of money within the council is allocated around public health… the air cooling, air cleaning, de-stressing factors are reducing the need for medical intervention for people; ES are providing those benefits to people, so can we lever in some [of that] money?" (TO15)
Strategic planning	9	22	"I think the first thing we want is a really intelligent strategy about what we want to do for the next 50 years… The priority would perhaps be restocking the city centre with trees that deal with air pollution and perhaps focusing on reducing flooding because we're anticipating more intense rainfall events with climate change." (TO7)

Most of the tree officers (54%) would like a comprehensive evidence base on local ES delivery and value to present to senior council staff; they felt that only an economic case for trees would increase political support and funding. Using such information to improve the perception of trees amongst citizens was also considered beneficial, though this was only mentioned by four tree officers (27%). A third of respondents were of the opinion that their department would take more of an ES approach in future if the benefits provided by their trees could be quantified in some way to improve understanding, while 33% also said that they would use information on ES directly to improve tree management:

> *"It was in the last few months that I read about that stuff (some species being 30% more efficient at removing water from the ground) and that has really improved my knowledge of the kind of things we need to do." (TO7)*

When asked specifically about whether (and how) a change to their urban forest could enhance provision of ES, all but one tree officer (TO12) thought it could. The most common suggestion of how to increase ES provision was to plant more trees in tree-deficient areas (60% of respondents),

followed by ensuring the right type of tree is planted and managed in the right place (27%), increasing tree species diversity (also 27%), and improving the health and condition of the tree stock (20%). One respondent (TO2) suggested a need for larger trees.

A greater understanding of the ES provided by trees was considered an important factor to help fund urban forestry activities. With recent cuts to local authority tree budgets across Britain, tree officers are starting to look to the private sector for financial support: 67% of interviewed tree officers already receive small contributions to their budget from corporate sponsorship, sale of tree management services to property owners, and corporate social responsibility activities. The majority of those interviewed (73%) were therefore keen to investigate the possibility of adopting some sort of 'beneficiary (or polluter) pays' approach. Eleven tree officers (73%) were of the opinion that businesses should contribute (e.g. through mitigation funds, sponsorship, environmental taxes, or planting on their own land), whilst 67% thought that citizens should contribute (via sponsorship, environmental taxes, community grants, or voluntary work). However, several tree officers had concerns around asking private stakeholders to pay the council for benefits that they already receive, and already contribute towards via council tax and business rates. Four tree officers thought some form of collaborative partnership, involving for example businesses, citizens, tourists, schools, public health and even other government entities may work, based upon beneficiaries paying for the ES benefits that they receive.

3.4 Discussion

3.4.1 Reactive public-sector management of environmental resources and issues

The typical approach to urban forest management in Britain is currently reactive, risk averse and complaints-driven. Eight tree officers (53%) placed an emphasis on austerity, introduced by the British government in 2010. Austerity reduced the money local authorities had available to spend over the period to 2015 by 22.2% (Innes and Tetlow, 2015), and while spending on statutory services (for example, social care) was fairly well protected, spending on non-statutory environmental services fell by 48.6% in this period (National Audit Office, 2014). Two-thirds of interviewed tree officers had seen their budgets decrease in recent years. A duty of care of society to reduce health and safety incidents meant that maintaining a healthy tree stock would always be a key priority for tree officers (regardless of funding). However, the provision of ES is not a statutory duty, but a 'luxury' (Mell *et al.*, 2013), even for 'aesthetic enhancement' unless the tree has been placed under a preservation order.

Austerity cannot shoulder the blame entirely, however. The Trees in Towns II survey revealed an average of 71% of tree maintenance work in England is carried out in response to health and safety risks or complaints from the public (a similar figure of 75% was reported by Scotland's TWIST study), but interestingly, the Trees in Towns II reporting period of 1999-2004 saw an overall *increase* in tree budgets (Britt and Johnston, 2008; Van der Jagt and Lawrence, 2015). One tree officer (TO8) said: *"To my knowledge it's always been this way - which is worrying"*, and suggested other factors are at play.

Indeed, reactive management is fairly common in public administration. Even in federal systems, where power is constitutionally dispersed – such as in the United States and Australia – public sector managers tend not to make changes unless forced to do so by outside pressures (Boyne and Walker, 2004). For example, Low and Carney (2012) show that local authorities in New South Wales, Australia took a proactive approach to the most important environmental issues (water and waste management), whilst lower priority issues (air and noise pollution) received only reactive management. The authors also suggest a correlation between reactive management and smaller budgets (Low and Carney, 2012). Meanwhile, several studies have found habitual modes of practice (or 'path dependence') preventing the uptake of nature-based solutions to climate change adaptation by local authorities throughout Europe (Naumann *et al.*, 2011; Matthews *et al.*, 2015; Wamsler, 2015).

The situation is even more extreme in countries with unitary political systems such as the UK, where innovative approaches developed by a particular council department or local authority are likely to be overruled or superseded by centrally imposed strategies (Boyne and Walker, 2004). The refusal of a council to adopt an urban forest strategy, as reported by TO13 in sub-section 3.3.3, is a perfect example of this. Reactive management is also apparent within central government; Bevan and Hood (2006) suggest that public sector decision-makers in the health sector actively seek improvements to services only where targets have been set, often to the demise of performance elsewhere. Meanwhile, policy decisions of the UK's Department for Environment, Food and Rural Affairs (Defra) have typically been driven by "short-sighted responses to public crises" (Rothstein and Downer, 2012: 785). Even recently, an investigation into the Government's treatment of floods in England found that "Parliament[ary] funding was initially cut and only increased due to the reactive funding injection following the winter 2013–2014 floods" (Environmental Audit Committee, 2016: 3). Despite further flooding, flood risk management reportedly remains reactive (Environmental Audit Committee, 2016).

A lack of strategic planning was apparent in the responses of the tree officers interviewed in this study. Only four of the 15 study cities currently have tree strategies in place, and two of these are

well over a decade old. Without a formal tree strategy – or other tree-related policies of a strategic nature – tree officers have little or no involvement in delivering their council's strategic policy. A key shift towards proactive management would come from the integration of trees and greenspaces into delivering the council's wider strategic objectives. A number of tree officers shared this reasoning, for example:

"As there isn't a management plan, there aren't any objectives." (TO8)

In overview, the non-statutory nature of a tree officer's duties (aside from risk management) has resulted in unprotected council tree budgets, low or non-prioritisation of strategic planning of the urban forest, and the continuation of a reactive approach to urban forest management. The interviews further suggested that urban trees are often seen and treated in a negative manner, with little focus being placed on finding solutions to specific disservices. This is concerning as a notable proportion (47%) of the tree officers interviewed revealed that complaints from citizens and businesses can have a strong influence on day-to-day management, even where it goes against their own better judgement. A counter to this would be a focus on positive and proactive urban forest management (planting and managing the right type of tree in the right place), so that ES benefits are enhanced and disservices (and thus complaints) are reduced (see for example Davies *et al.*, 2017a). How this may be achieved is discussed below.

3.4.2 Delivering regulating ecosystem services through green infrastructure planning

The interviews revealed that the majority of tree officers do not currently manage their urban forests for regulating ES, though there is a desire and an understanding of the benefits that can be achieved from doing so. The Trees in Towns II (Britt and Johnston, 2008) and TWIST (Van der Jagt and Lawrence, 2015) surveys provided no evidence to suggest that an ES approach is being taken in England and Scotland respectively. Together with the current study, this suggests that (with exceptions such as TO5) regulating ES are not currently a priority in the day-to-day management of Britain's urban forests.

Political support from a local authority's councillors and senior management was revealed as a potential driver for a move towards proactive, ES-based urban forest management, although such support was not always forthcoming. Tree strategies had only been adopted in 27% of the study cities, suggesting little progress since the Trees in Towns II survey revealed that only a quarter of responding English local authorities had published tree strategies (Britt and Johnston, 2008). However, there is progress in the *content* of tree strategies, with those published most recently in Britain addressing ES (particularly those relating to climate change adaptation) in their visions,

aims, objectives, principles, policies, actions, and recommendations.[36] A key driver for this might be the UK Government's National Planning Policy Framework and National Adaptation Plan which both encourage local authorities (particularly those with large and/or dense populations) to improve climate resilience through enhancements to green infrastructure (DCLG, 2012; Defra, 2013b). Cambridge and Wrexham councils have additionally used tree canopy and i-Tree Eco surveys to inform their policies (Wrexham County Borough Council, 2015; Cambridge City Council, 2016).

Examples from Europe suggest that progress is mixed: urban forest strategies in Barcelona and Dublin refer to ES only in passing (Barcelona City Council, 2011; Dublin City Council, 2016). Helsinki's puts 'securing ES' as its main objective, though delivering this only amounts to considering the effects of decision-making on the long-term vitality of ES provision (City of Helsinki, 2014). Sweden, Denmark and Switzerland all prioritise the provision of cultural services (e.g. recreation and education) in their objectives for urban woodland management (and to a lesser extent nature conservation), but regulating services receive very limited explicit attention (Nielsen *et al.*, 2013; Wilkes-Allemann *et al.*, 2015).

As with public sector decision-making in Europe more generally, there may be several reasons for this. For example, path dependence reducing decision-makers' interest in new, nature-based, solutions (Matthews *et al.*, 2015); an absence of long-term thinking (Ojea, 2015); or perhaps poor presentation of data linking regulating ES with outcomes relevant to decision makers (Turner and Daily, 2008; Wright *et al.*, 2017). However, Capotorti *et al.* (2016) suggest that the regulating ES provided by urban forests have been gaining increasing attention in Europe since publication of the EU green infrastructure strategy (European Commission, 2013). Using a case study of Rome, the authors report that scientific information on noise mitigation, temperature regulation and air purification has been incorporated into technical guidelines for tree planting in the city (Capotorti *et al.*, 2016).

Urban forest strategies are more common in the United States, Canada and Australia, and regulating ES are addressed more convincingly. In Australia, tree strategies have placed emphasis on enhancing tree benefits, with Melbourne seeking to reduce the urban heat island effect through increasing canopy cover (City of Melbourne, 2012). In Canada, urban forest master plans have been adopted in 33 municipal authorities across nine provinces/territories, with almost half of those (45%) following publication of the Canadian Urban Forest Strategy 2013-2018 (Tree

[36] These include those published by Nottingham City Council (2013); Bournemouth Borough Council (2014); Wrexham County Borough Council (2015); Cambridge City Council (2016); Walsall Council (2016); Birmingham City Council (2018); and Leicester City Council (2018).

Canada, 2012). A review of plans published prior to the national strategy suggested that "ecological, social, and economic considerations lack specificity and operational clarity" (Ordóñez and Duinker, 2013: 36). However, since then, regulating ES have been incorporated into visions, strategic goals and operational principles, with Toronto in particular supporting theirs with an i-Tree Eco study (Toronto City Council, 2013). In Ontario, an interview-based study with 18 urban foresters revealed that "the provision and maintenance of ES were, second to tree establishment, the most important consideration in urban forest management" (Fontaine and Larson, 2016: 223).

In the United States, a survey of 599 municipal arborists found that 73% are moderately to very engaged in managing trees and other green space assets to produce ES such as heat amelioration and stormwater attenuation, though no information was provided on how they do this (Young, 2013). Urban forest masterplans are common across the country and frequently draw on the results of i-Tree studies to support regulating ES objectives (Hauer and Peterson, 2016). Many set short, medium and long-term actions for government departments and other organisations to enhance, quantify, value or communicate the benefits provided by the urban forest; in Portland these actions are updated on an annual basis (Portland Parks and Recreation, 2016). This is advocated by urban forest guidelines published by the United Nations Food & Agriculture Organisation (UN FAO), which state that "urban forest plans should provide a framework for actions" (Salbitano *et al.*, 2016: 32).

Looking at green infrastructure strategies more broadly, these also appear to have been adopted by only a minority of UK local authorities; many are out of date, and carry little clout in planning terms (Scott, 2019). Lennon *et al.* (2017) reveals that there are few studies worldwide that critically reflect on whether the theory of ES provision from green infrastructure is actually being implemented through planning practice. A review of high-profile academic, policy, guidance and strategic delivery documents on green infrastructure planning worldwide was undertaken by Mell (2014). The review suggests that climate change is moderately well addressed across all countries/regions (the UK, United States, Europe, Asia and Australasia); water management is discussed in far greater depth in the United States than in Asia; whilst ES more broadly are – surprisingly – least well addressed in Australasia (Mell, 2014).

More recently, a study of approaches to green infrastructure planning in Europe found 11 out of the 14 plans to set objectives for improving quality of life, i.e. relating to cultural ES (Grădinaru and Hersperger, 2018). However, only seven of these plans included measures for water management, just five did so for climate change adaptation, and none sought to address air pollution (Grădinaru and Hersperger, 2018). A review of green infrastructure strategies produced by seven front-running local authorities in the UK suggests that green infrastructure is being

positioned as an asset, with evidence of associated ES provision (Scott *et al.*, 2017). For example, Birmingham's green infrastructure strategy, adopted in 2013, incorporates measures for quantifying and addressing issues of flooding and climate regulation, and integrates these with wider spatial planning (Birmingham City Council, 2013; Scott *et al.*, 2017).

The UK tree officer interviews revealed environmental issues (poor air quality, surface water flooding and/or heat islands) to be present in the cities involved in this study, a general understanding amongst tree officers of nature-based solutions, and at least some political support for urban forests. Given the variability in ES content amongst tree and wider green infrastructure strategies adopted in the UK and elsewhere, the publishing of an urban forest guidance document by the UN FAO that facilitates production of strategies incorporating ES-specific actions is extremely welcome. More recently, the UK government has published an urban forest 'manual' (Barbrook *et al.*, 2018) and a consultation document on protecting and enhancing urban forests (Defra, 2018c). The latter proposes 'best practice guidance on Tree and Woodland Strategies', including valuation of the social, economic and environmental benefits that trees and woodlands provide; whilst the former advocates planting the right trees in the right places with regards to ES provision and tree survival. However, even if regulating ES are considered to be important by tree officers and their wider council colleagues, competing objectives and limited funds may mean that central government stimuli are required.

3.4.3 Constraints to proactive, ecosystem services-focused decision-making

The interviews revealed that tree officers within British local authorities are trying to move from a risk-based/reactive approach to proactive and ES-focused management. Key constraints to enacting this change were found to relate to funding, governance, apathy and poor understanding (each considered further below). These results agree with those of Britt and Johnston (2008) and Van der Jagt and Lawrence (2015) who previously revealed similar restrictions for proactive urban tree management: limited financial and staff resources; poor communication amongst local authority departments; poor public and political support for trees; and a lack of data on the local tree stock. Similarly, a lack of data on urban trees and a lack of investment were identified as major obstacles to improving approaches to urban tree management in towns and cities across Europe (Pauleit *et al.*, 2002).

The four categories of constraints to adopting an ES approach in decision-making identified in this study are also recognised in the wider literature. Turner and Daily (2008) identify a deficiency of detailed information linking ES with wellbeing benefits at scales useful for decision makers, and Guerry *et al.* (2015) suggest that government, business and civil society are not working together

closely enough to ensure that ES are integrated into every day decision-making. Ojea (2015) reports issues of poor governance structures, public participation and inappropriate financial mechanisms preventing ecosystem-based adaptation to climate change. Similarly, a study of the implementation of ES in urban planning in cities in Europe and the United States identified the science-policy gap and, specifically, the limited connection of ES with policy problems as the key barrier (Kremer *et al.*, 2016). Scott *et al.* (2017) suggest that green infrastructure, underpinned by an ES approach, has failed to establish as a core spatial planning concept for similar reasons. These include "[in]sufficient quantifiable indicators and delivery mechanisms for its management and use; its requirement for long-term planning and management often conflicting with incentives for short-term optimisation prevalent in industry and politic arenas; and its multifunctional nature conflicting with 'silo' problem-solving nature of Governmental institutions" (Scott *et al.*, 2017: 5).

Britt and Johnston (2008) state that it is the responsibility of tree officers to ensure that the public and the council start to view urban trees as assets rather than as liabilities. As one interviewee commented, this is not always possible:

> *"We used to have a ranger service which was a perfect vehicle to deliver a lot of these [ES] concepts… These were the first lessons that we could get kids involved in, and that starts to bring the family members in and that's one of the ways I saw the message had been delivered in the past. But… now we've got two rangers left out of 40." (TO11)*

The current study suggests that communicating the benefits of trees to politicians and the public has not been possible due to the reduction in funds and staff, and related to this, the lack of data on local ES provision. However, Moffat (2016) suggests that it is the failure of urban forest professionals in Britain to adequately communicate with politicians and the public about the benefits of trees that has *caused* the reduction in support and funding for Britain's urban forests. The author suggests this is due in part to scientific reports overplaying the likely benefits that urban trees can bring and ignoring important aspects such as varying temporal and spatial scales, trade-offs between ES, and tree disservices (as people can lose faith when they can't see the promised benefits) (Moffat, 2016). Recent publications including Lafortezza and Chen (2016) and Davies *et al.* (2017a) seek to help address this issue, though a publication itself cannot solve the problem – the information needs to reach and be taken on board by the politicians and public alike. Whether it is falling levels of support that is preventing tree officers in Britain from improving the image of trees, or vice versa, many are finding themselves caught in a downward spiral at a time of increasing threat from pests, diseases and climate change. Urban canopy cover and, therefore by inference, tree numbers are reported to be decreasing across Britain's towns and cities (Doick *et al.*, 2016b). Attention must now be turned towards methods for increasing

urban forest support and funding if this trend is to be halted and reversed and if urban society is to continue to benefit from ES provided by trees.

3.4.4 Promoting an ecosystem services approach in local government

The majority of suggestions made by the interviewed tree officers were about increasing levels of understanding and support for trees amongst the public and other council departments by quantifying and valuing the ES they provide – helping to address 'information failure'. Previously, Vandermeulen *et al.* (2011) and Corona (2016) have also argued that placing economic values on green infrastructure is necessary to convince politicians, citizens and other stakeholders of their usefulness. A review of worldwide green infrastructure policy documents by Mell (2014) suggests that the short- and long-term economic benefits of green infrastructure have generally been poorly discussed – particularly in the United States, Asia and Australasia; whilst funding of green infrastructure interventions is also poorly addressed in European documents. Nevertheless, in the United States, "New York City, Boise, Minneapolis and many other cities found that monetizing the value of their municipal forest services led to increased appreciation of trees and tangible program enhancements" (Soares *et al.*, 2011: 69). Similarly, the i-Tree Eco survey in Torbay, England – which monetised the carbon storage/sequestration, air purification and stormwater attenuation benefits of the urban forest – resulted in an additional £25,000 being added to the council tree budget (Doick *et al.*, 2016a).

The i-Tree Eco software still only partially addresses the heat amelioration service provided by urban trees, quantifying the energy saving effects of trees to buildings, and not their impact on surface, air and radiant temperatures and the importance of this to human comfort. Furthermore, the valuation is currently not valid in Britain as it is based on US housing stock. Accurate quantification of heat amelioration by Britain's trees could be a valuable communication tool, as even many of the interviewed tree officers were unaware of the extent of this benefit. Premature deaths from heat-related conditions in the UK are estimated at 2,000 a year and this is expected to triple by the 2050s (Committee on Climate Change, 2017), affecting the East Midlands, South East, West Midlands and East of England in particular (Hajat *et al.*, 2014). Trees can be a significant part of the solution (Gill *et al.*, 2007; Ziter *et al.*, 2019), however neither the message on the severity of changing climate or the roles of trees in combatting it were found to be prevalent amongst the tree officers interviewed.

The UN FAO's urban forest guidance document recommends "that savings in healthcare costs generated by urban forest ES are taken into account in relevant policies and duly incorporated in the financial accounts of governments" (Salbitano *et al.*, 2016: 49), and this is starting to be

considered in Britain. For example, councils in Sheffield, Birmingham and Greater Manchester have developed natural capital accounts to incorporate costs and benefits associated with their green infrastructure (Vivid Economics, 2016; eftec, 2018; Hölzinger and Grayson, 2019). Meanwhile, a Dutch 'TEEB for Cities' study has developed a tool to incorporate the financial benefits of green spaces within municipal balance sheets (though only two of the eight study cities subsequently implemented the tool) (van Zoest and Hopman, 2014). Capital Asset Value for Amenity Trees (CAVAT) is a tool increasingly used in the UK for monetising the amenity value of urban trees – either individually or for the tree stock as a whole – so that they may be seen as public assets rather than liabilities (Doick *et al.*, 2018). It is likely that national government support will be needed to ensure natural capital accounting is carried out by local authorities and that this additional information leads to new policy and action in support of the urban forest.

In the absence of sufficient tree management budgets, novel funding approaches that draw in financial (or in-kind) support from citizens, businesses or other council departments are needed – helping to address 'institutional failure'. 'Payments for ecosystem services' (PES) was specifically referred to by one of the interviewed tree officers while also raising concerns about how it would work in practice:

> *"It's all very well having these payment for ES systems built in but who's going to broker the payment, and how… [do you ensure] it would be quality controlled, and how do you achieve landscape scale improvements from disparate and reductive payments coming in?" (TO5)*

PES schemes have rarely been used in urban settings due to perceived complexities around ES interactions, and the vast number of potential buyers and sellers potentially increasing transaction costs and the risk of free riding (Wunder, 2008; Wertz-Kanounnikoff *et al.*, 2011). Nevertheless, urban PES schemes have been piloted in Britain, with some success. The Defra PES pilot schemes in Hull and Luton, for example, found buyers (the councils, local water companies, residents and some businesses) who were willing to pay for green infrastructure improvements due to stormwater attenuation benefits (MacGillivray and Wragg, 2013; Brewer *et al.*, 2014). The research did not however investigate the potential role of trees for providing this service, and thus further research would be required to test this as a route for novel funds for the urban forest.

In terms of strategic planning, Kenney *et al.* (2011) propose a framework of 25 indicators that local authorities could use to shift the focus of urban forest management towards more easily quantifiable and sustainable results. These relate to the socio-political constraints to adopting an ES approach identified through the present study, for example the awareness of tree benefits by the public; the level of private and public funding; and the suitability of the maintenance regime and location of the tree for provision of benefits (Kenney *et al.*, 2011). This latter point is key, as a

number of the interviewed tree officers share the popular yet overly simplistic view that provision of (all) ES can be enhanced simply by increasing canopy cover. In reality, urban forest ES provision depends on the type and structure of the trees, their location, ownership and management, and the proximity of the tree/woodland to people (Davies *et al.*, 2017a). Furthermore, "the inclusion of all possible benefits that urban trees can bring presents too wide a picture and hinders focus on those goods and services which would really make a difference in the particular circumstances" (Moffat, 2016: 7).

Kenney *et al.* (2011) concede that assessing urban forest planning and management against such a large number of indicators may seem overwhelming, but reveal that such an approach has already been successfully adopted in three Canadian municipalities. As well as saving time and money going forwards, proactive, strategic planning such as this will assist local authorities in moving away from 'path dependence'. Similarly, Hansen *et al.* (2016) identify factors for successful implementation of green infrastructure in a number of European case study cities. Such factors include linking green infrastructure to pressing challenges (e.g. flooding and heat islands); identifying advocates amongst those with political clout; and increasing resource availability by involving different council departments and accessing private sector funds (Hansen *et al.*, 2016).

The proactive approach advocated by these authors is similar to the action plans associated with urban forest strategies in the United States. Importantly they seek to itemise the opportunities and threats to 21st century urban forest management and seek solutions to these within specific timeframes. Five of the tree officers interviewed in this study were preparing tree strategies, though it was not clear to what extent ES provision would be prioritised, or if and how the strategies would be linked to other council departments. One exception was TO15 who intended to link the new strategy with the development of a natural capital planning tool, conducting an i-Tree Eco survey of the city's trees, and working more collaboratively with the public health department. Echoing the urban forest guidelines published by the UN FAO (Salbitano *et al.*, 2016) and more recently by the UK government (Barbrook *et al.*, 2018; Defra, 2018c), this study recommends that all cities (in the UK, Europe, and potentially beyond) should have an up-to-date tree strategy that takes an ES approach, is intentionally proactive, and is underpinned by an action plan, delivery indicators, and a commitment to regularly review and revise the strategy.

3.4.5 Study limitations

Just 54% of the local authorities contacted (those representing Britain's most densely populated cities outside of London) took part in the study. It may be that tree officers from these other cities have even fewer resources for proactive urban forest management, and so could not find the

time to respond. Alternatively, understanding of and enthusiasm for ES could potentially be lower amongst the non-respondents. Nevertheless, for an in-depth, exploratory, qualitative study such as this, a response rate of 54% is considered acceptable.

3.5 Conclusions

The paper published for Objective 1 of this thesis contributes to the literature by investigating explicitly and for the first time, whether and how regulating ES influence urban forest management; and what socio-political constraints local authorities face in using urban trees as a nature-based solution to the heat, flood and air quality problems associated with densely populated cities. It highlights the necessary drivers for adopting an ES approach to urban forest management, and drawing on both the international literature and the interviewed tree officers, sets out a number of recommendations to take this further.

Two-thirds of the tree officers indicated that they have a reactive rather than proactive approach to managing their urban forest, focused on reducing risk and complaints. This is largely due to declining tree budgets and a lack of local strategic policy, though it is also partly a consequence of central Government thinking, where a reactive approach to environmental decision-making is common. An ES approach is rare within local authorities, particularly in Europe, due to short-term thinking, habitual modes of practice, and poor understanding of the link between land use change and outcomes amongst decision-makers. For example, only two of the tree officers gave examples of how they currently manage their urban forest to benefit from reductions in the urban heat island, air pollution and stormwater flooding.

Just 27% of the study cities had published tree strategies, and only one of these included specific recommendations for enhancing the provision of regulating ES. This situation appears to be fairly common throughout Europe, and redressing it is an important next step. Having political support for trees and the benefits they provide was seen as a key driver to adopting an ES approach to urban forest management. This however has to be underpinned by local data and the economic case for trees, and obtaining these are recommended to the study cities as important next steps; for example through the application of an i-Tree Eco study. Awareness-raising is also key, as evidenced in the United States and Canada. While such measures can improve funding for urban forests, a natural capital accounting approach may also be necessary to bring in funding from other council departments, and public-private PES schemes could be used to encourage businesses and citizens to contribute.

This study was conducted with just 15 of the UK's 28 most densely populated cities (excluding London), and as such may not be indicative of or relevant to all local authorities. Nevertheless, the findings are thought to be relevant to urban areas across Europe (and potentially elsewhere) where trees may offer a cost-effective solution to those common issues of urbanisation: surface water flooding, poor air quality and urban heat islands. It is recommended that UK and European cities take heed of urban forest guidelines published by the UN FAO and Defra, and attempt to replicate the proactive approach adopted in North America (i.e. action-based urban forest strategies supported by i-Tree studies). Addressing socio-political constraints to incorporating ES into local authority decision-making more broadly is also recommended.

Going forwards it would be useful to conduct further research into the feasibility of PES schemes and natural capital accounting to increase funding for urban forests from the private and public sectors, respectively. Using a case study approach for Southampton, UK, the rest of this thesis seeks to provide the necessary research regarding the feasibility of an urban forest PES scheme funded by the private sector – specifically businesses (Objective 2) and citizens (Objective 3).

Chapter 4 Business attitudes towards funding ecosystem services provided by urban forests

A version of this chapter was published in the journal *Ecosystem Services* in August 2018 as Davies *et al.* (2018). The paper was written solely by the researcher; her supervisors (the co-authors) provided comments on several drafts.

4.1 Introduction

Predicted increases in the frequency and intensity of heatwaves and extreme precipitation events, as well as worsening ozone concentration, will impact significantly on businesses and communities in city environments (European Environment Agency, 2016a). Supporting other engineering and policy solutions (such as air conditioning units, levees, and low emission vehicles), nature-based solutions to these climatic and health issues are increasingly being considered throughout the world (Baró *et al.*, 2015). Green infrastructure – especially urban forests – has a crucial role to play in helping urban areas become more resilient to challenges through the provision of regulating ES such as heat amelioration (Doick and Hutchings, 2013); stormwater attenuation (Armson *et al.*, 2013); and air purification (Escobedo and Nowak, 2009).

There are calls for additional tree cover in cities worldwide in order to improve resilience to climatic changes and enhance quality of life (e.g. Salbitano *et al.*, 2016; Doick *et al.*, 2017; Ziter *et al.*, 2019). However, funding for urban trees and other green infrastructure has declined in many cities, particularly in Europe, exacerbated by government austerity (van Zoest and Hopman, 2014; Kabisch, 2015). 'Payments for Ecosystem Services' (PES) – funded by businesses and/or citizens – could pose a potential solution (Bade *et al.*, 2015; Davies *et al.*, 2017b).

Various definitions of PES exist, with the narrow definition of Wunder (2005) and the broad definition of Muradian *et al.* (2010) being the most commonly reported. This lack of agreement on the definition and conceptualisation of PES, combined with the wide variation in schemes on-the-ground, has led Martin-Ortega and Waylen (2018) to suggest that imposing a universal definition of PES may not be appropriate. Nevertheless, drawing on these studies and on UK PES guidance (Smith *et al.*, 2015), for the purposes of this thesis, PES is defined as 'a transfer of resources between ES buyers and sellers that aims to improve provision of ES for the benefit of society and the environment'. The following principles apply:

- Voluntariness – stakeholders ideally enter into a PES agreement on a voluntary basis, however governments may act on their behalf, or regulate involvement, if necessary.
- Payment source – payments are made by the beneficiaries of ES (citizens, businesses, or governments acting on their behalf). This includes those benefitting from reputational enhancement or actions that compensate for (unregulated) environmental harm.
- Conditionality – payment is conditional on the delivery of quantified ES, or on the implementation of robust land use practices proven to deliver ES benefits.
- Additionality – ES benefits (or proxy land use practices) are over-and-above the baseline (or business-as-usual) level, and do not lead to the loss or degradation of ES elsewhere.

There are currently few documented examples of PES schemes located entirely in urban areas – especially those funded by businesses. During 2012-2015, Defra funded three pilot projects to investigate the potential for urban PES schemes in the UK, each focused on the enhancement of ES from green (or blue) infrastructure. Those in Luton and Hull were considered to be a success – though interest from the business community was limited – while that in Manchester failed to gain any business support at all (Defra, 2016a). Though not labelled as PES, there are other urban schemes with similar objectives. For example, a non-profit organisation in the United States (City Forest Credits, 2017) has had success selling carbon and quantified co-benefit credits to private sector buyers for urban forest projects in cities nationwide. Also in the United States, NatureVest (2017) has launched a private-to-private stormwater trading market in Washington D.C. to facilitate developers in funding green infrastructure projects to reduce stormwater runoff in the city, but it is unclear what the take-up has been. Other schemes have recently been launched in Australia, Italy and the UK to varying degrees of success, though these seek funding from businesses directly for tree planting rather than for the ES that these trees provide.

Preferences and monetary values for ES are usually determined via surveys of citizens; by contrast, business demand for ES has largely been ignored in the literature. The few published studies on the subject suggest that business attitudes towards (investing in) ES are generally positive, but with some business owners unaware of ES and others with perceptions that may prevent increased ES provision (Wolf, 2004a; Koellner *et al.*, 2010). In rural areas, businesses have shown interest in paying for carbon sequestration in order to enhance their reputation (Koellner *et al.*, 2010; Reed *et al.*, 2013). Paying to enhance water quality and quantity is of interest to businesses that depend on water as a major input to their business activities, whilst biodiverse habitats may tempt more visitors and tourists to an area (Koellner *et al.*, 2010; Reed *et al.*, 2013; Reddy *et al.*, 2015). In an urban context, businesses' willingness to invest in specific ES is yet to be determined, however, enhancing visual amenity is likely to be of most interest, as customer spend and employee satisfaction are likely to be higher in aesthetically pleasing locations (Wolf, 2004a).

Despite the likely climatic, health and corporate benefits to businesses of investing in ES delivery from their local green infrastructure, it is currently unclear from the literature whether businesses would be willing to do so. Given the obvious and urgent need for investment in nature-based solutions to city problems, research into the possibility of corporate funding is increasingly necessary. The purpose of this part of the thesis is therefore to identify business attitudes towards private sector investment in urban forest ES by means of a PES scheme – and the factors influencing such attitudes – using a case study of the UK city of Southampton. To this end, three research questions were posed:

1. What are business attitudes towards urban trees and the ES they provide?
2. What are business attitudes towards private sector investment in urban forests?
3. What are business preferences regarding the operation of an urban forest PES scheme?

4.2 Materials and methods

4.2.1 Data collection

Interviews were carried out with senior business representatives (such as sustainability managers, directors and business owners) from 30 businesses operating in the Southampton area, during December 2016 to April 2017. This represents a response rate of 30%, with 84 businesses and five business membership organisations having initially been contacted. Businesses of all sizes and sectors were targeted; the methods used to recruit businesses initially included:

- Contacting existing business contacts of staff at the University of Southampton – 11 out of 31 participated;
- Approaching attendees of two business functions held in Southampton – ten out of 19 participated; and
- Advertising the study in the newsletters of five business membership organisations covering the Southampton area – five out of an unknown number participated.

Due to fairly low numbers of responses – particularly from certain industry sectors – an additional method of recruitment was introduced. A total of 34 Southampton businesses operating in these sectors were contacted directly via email; four of whom participated in the study. The difficulties encountered in recruiting participants also meant that just 16 of the 30 businesses included in the study were physically located within the area administered by Southampton City Council. Six were located in the adjacent local authority areas of Eastleigh, Test Valley and the New Forest (largely with Southampton postcodes), whilst nine were based elsewhere in the county of Hampshire (e.g.

Winchester or Fareham). In these cases, staff and/or customers were known to reside within Southampton, and all business representatives were asked to respond as if financial contributions would be going to their local council.

The interviews were semi-structured, with business representatives initially answering 26 closed questions provided in advance. Questions were grouped into six related topics, namely: costs and benefits of urban trees; relationship between business and the natural environment; public-private funding for urban trees; arranging the financial transaction; conditions of involvement in a public-private funding scheme; and, 'about your business'. These topics were chosen for several reasons – firstly, to add to the sparse literature on business interest in trees and the funding of ES (see sub-section 2.2.1). Secondly, to ascertain whether a PES scheme of this nature would be feasible and desirable given the lack of real world examples (see subsections 2.2.2 and 2.2.5). Thirdly, to find out which aspects of PES design would be important for attracting and maintaining investment in this context, given the lack of consensus in the literature (see sub-sections 2.2.3 and 2.2.4). And finally, to check the representativeness of respondents. The full list of questions can be found in **Appendix C**. During the interview, follow-up questions were employed to enable respondents to elaborate on their answers. Interviews were recorded and lasted for 27 minutes on average, ranging between 13 and 53 minutes.

Ethical approval for this research was granted by Ethics and Research Governance Online (ERGO 24254) at the University of Southampton. Participating businesses have been provided with linked anonymity, thus comments from individuals have been identified as 'BR01', up to 'BR30' rather than ascribing these to particular named businesses.

4.2.2 Data analysis

Qualitative and quantitative analyses were performed on the interview data. The closed questions were primarily 'yes' or 'no' (resulting in binary variables), though some involved making a choice from multiple answers (resulting in categorical or ordinal variables). Non-parametric chi-squared (χ^2) tests for associations between the variables were performed using the software package 'IBM SPSS Statistics 24' (IBM, 2016). Due to the small sample size, categorical and ordinal variables were converted to binary variables before undertaking these tests to increase the expected frequency of each cell (Knol and Berger, 1991; Rupp, 2008). With all variables being binary, it was therefore necessary to apply continuity correction to the results (Haber, 1980). It was not deemed appropriate to also apply a Bonferroni correction for multiple tests, as this is overly strict – particularly for a small and exploratory study such as this (Nakagawa, 2004). These quantitative results (which can be found in **Appendix C**) should therefore be interpreted with caution. A three-

point Likert scale was used to identify respondents' attitudes towards tree benefits and tree nuisances – the mean scores for these were compared using a Student's t-test. Statistical results are reported as χ^2 or t statistics, along with their respective probabilities (P) and degrees of freedom (v). Descriptive statistics, i.e. the percentage of respondents answering yes or no to closed questions, are also provided.

As with the local authority interviews, qualitative analysis was performed using the software package 'Nvivo v.11' (QSR International, 2015) using a thematic approach, following the process outlined by Braun and Clarke (2006). However, there is a notable difference in the approach to analysis between the tree officer interviews and the business interviews. Whilst the former were transcribed verbatim from start to finish, the latter were only transcribed at the points where business representatives were answering openly, giving their opinions about a particular question (usually when prompted to do so by the researcher). Full data on themes and codes for the qualitative analysis can be found in **Appendix C**. Qualitative findings are presented in section 4.3 as numbers of respondents commenting on a theme and the numbers of comments they made. Direct quotations were also selected to illustrate the key points, as suggested by Braun and Clarke (2006).

The geographic location (i.e. the local authority administrative area as well as the grid reference), size (micro, small, medium or large) and broad industry sector[37] were also collected for each of the interviewed business representatives. This was to enable identification of business characteristics that may have influenced the interviewees' responses.

4.3 Results

Of the 30 interviewed businesses; 33% were classified by Companies House (2016) as micro, 20% as small, 10% medium, and 37% as large.[38] Given that 89% of all Southampton's enterprises are micro, this size was under-represented in the sample, and all other sizes over-represented (Nomis, 2016). Businesses operating in the professional, ICT and transport sectors were over-represented in the sample compared with the average for Southampton (Nomis, 2015), whilst education, health and the wholesale/retail/motor trades were under-represented. Business

[37] A total of 20 broad industry sectors have been used in the analysis, based on the UK Standard Industrial Classification (UK SIC) 2007 Codes (Office for National Statistics, 2009).

[38] Companies House classifies micro businesses as those with ≤ 10 employees and/or turnover ≤ £632,000; small as having 11-50 employees and/or turnover ≤ £6.5 million; medium with 51-250 employees and/or turnover ≤ £25.9 million; and large as > 250 employees and/or turnover > £25.9 million.

sector relates to the UK Standard Industrial Classification of Economic Activities (Office for National Statistics, 2009).

The locations of responding businesses were mapped using the software package 'ArcMap 10.5' (Esri, 2016). This revealed that all but one business (BR05) was located in an area defined by Rowland *et al.* (2017) as urban or suburban. Six businesses were located in areas that exceed the EU annual mean limit for NO_2 of 40 μg/m^3 (Defra, 2015b). Nine were in locations with at least a moderate probability of surface water flooding (above 1m depth in a 1 in 100 year rainfall event, or above 0.1m in a 1 in 30 year event) (Environment Agency, 2016). Nine businesses were located in those parts of the city shown to experience the highest surface temperatures (Osborne, 2016). In total, 18 businesses were in locations affected by at least one of these three environmental issues.

4.3.1 Business attitudes towards trees and the ecosystem services they provide

Perceived benefits and environmental risk to businesses

The attitude of businesses towards urban trees was overwhelmingly positive, with 26 respondents making 79 positive statements. These related principally to cultural and regulating services that trees provide to businesses and their staff (54 references from 21 respondents). Six respondents also stated that urban trees have financial benefits for their businesses, though these are unquantified. Positive statements included:

> *"I think there's a general consensus [amongst the local businesses] that they'd rather be in a green area with trees." (BR22)*
>
> *"Indirectly the wellbeing [benefit provided by urban trees] is related to the prosperity of the business... if I feel better I'm going to be better at my job and I'll go out and get more business." (BR24)*
>
> *"[Trees] reducing flooding and staff sickness… is a benefit [to our organisation]." (BR27)*
>
> *"If you've got something that looks nice and it's kept nice, then you've got a higher chance of that area making more money and getting more customers." (BR29)*

In terms of the specific ES that respondents considered most important to their businesses, improved aesthetics of the local area was very or quite important to 93% of respondents, followed by improved air quality and employee health (Figure 4.1).

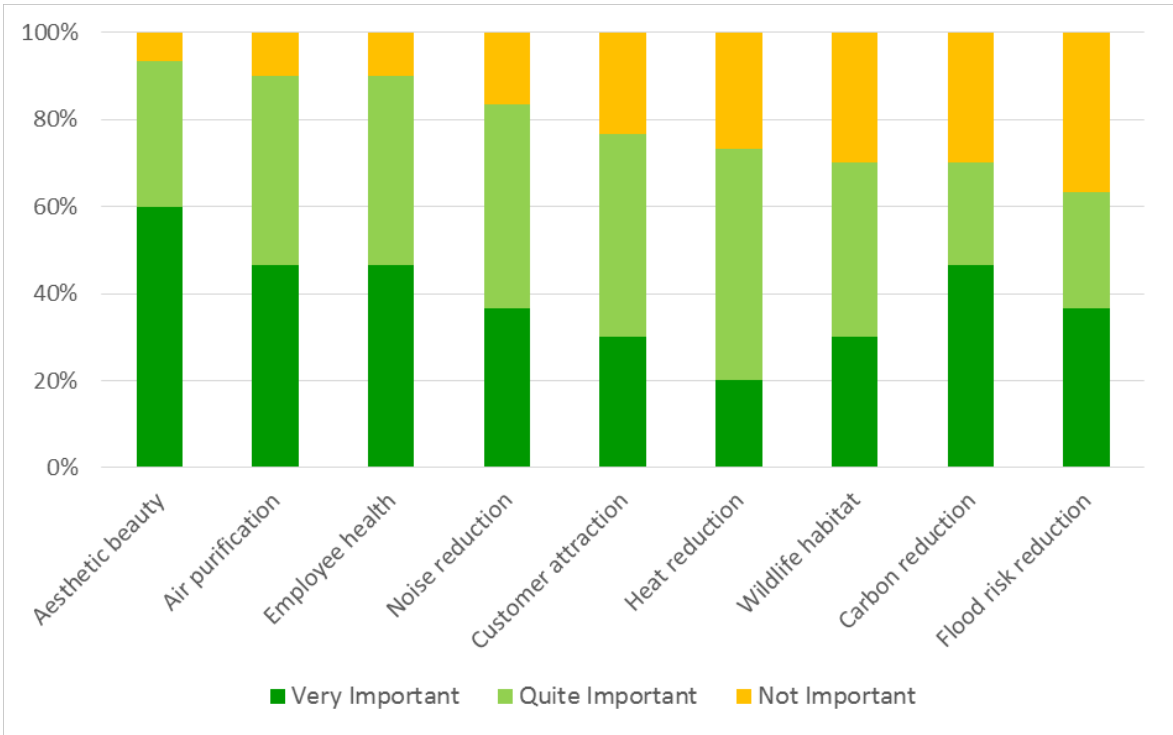


Figure 4.1: Proportion of businesses who consider tree benefits to be important

The top three benefits rank the same regardless of whether 'very important' is considered alone or in conjunction with 'quite important'. However, reduced summer heat was ranked last of the nine specified benefits for 'very important' and 6th for 'very' and 'quite' important combined, and vice versa for reduced local flood risk. This is perhaps because only a minority of the businesses have been affected by extreme weather events: eight have experienced flooding of their buildings, car parks, or access road; whilst five have experienced overheating buildings during heatwaves.

Two-thirds of respondents were concerned about the potential impact of climate change on their business and/or the city overall (64 references from 27 respondents related to this point). This was particularly so for those located in areas with at least moderate risk of surface water flooding, significant at the 5% level ($v = 1$, $\chi^2 = 4.464$, $P = 0.035$). Medium-large firms also tended to be more concerned about climate change than micro-small ones ($v = 1$, $\chi^2 = 2.829$, $P = 0.093$). Overall, respondents were most concerned about flooding (13 respondents), air pollution (n=10), heatwaves (n=9), sea level rise (n=3) and energy prices (n=3), but only a minority (23%) specifically mentioned trees as a nature-based solution to many of these issues. Comments included:

> *"Flood risk is a big one for us... The multi-storey car park is usually the worst for it... [If there were] green areas, soakaways, [or] SUDS in that area, I'm sure it would help reduce that risk." (BR11)*
>
> *"Southampton has got some of the worst air quality in the UK." (BR23)*
>
> *"I reckon a few days of 40 degree heat here would cripple this building." (BR21)*

Perceived nuisances and governance of the urban forest

Despite this overall positivity for trees, and concern about the environment, 16 respondents made 26 negative or ambivalent comments about trees and the services they provide, including:

"Structural damage from tree roots is probably one of our biggest costs." (BR12)

"I don't think [my customers] would really care if there are trees or not or whether I contribute to them being around in the local environment." (BR03)

"I think the climate change issue is not going to be changed by urban tree planting." (BR12)

Of the 30 respondents, 83% reported at least one tree disservice as being 'quite' important to their business, whilst 50% found at least one disservice to be 'very' important. Nevertheless, each specific tree nuisance affected only a minority of businesses, and overall they were considered fairly unimportant: the mean rating given to the nuisances was significantly lower (at the 1% level) than that given to the benefits ($v = 550$, $t = -12.193$, $P = 0.001$). Bird and aphid excrement falling on cars, trees obstructing business signs, pollen allergies, and structural damage were of greatest concern, affecting 37-43% of respondents (see Figure 4.2). Nine respondents (30%) said they incur expenditure associated with tree nuisances, in particular for clearing up fallen leaves and repairing structural damage. The relationship between incurring expenditure and finding leaf fall to be a major nuisance was significant at the 5% level ($v = 1$, $\chi^2 = 4.836$, $P = 0.028$).

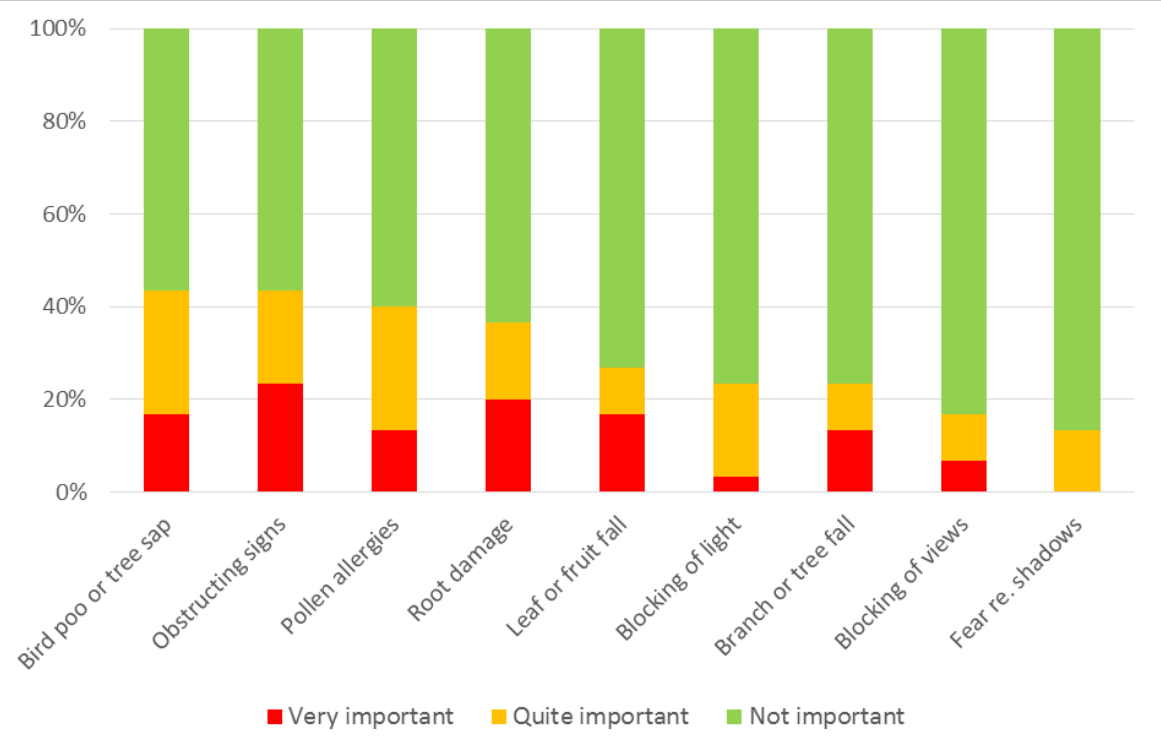


Figure 4.2: Proportion of businesses who consider tree nuisances to be important

In terms of the governance of Southampton's urban forest, 33% of business respondents showed interest in collaborative decision-making via a steering group, whilst 10% would respond to consultations on tree planting and maintenance. However, due to resource constraints, the majority of respondents (40%) would simply like to be informed of the council's decisions, whilst 17% want no involvement at all. The size of the interviewed businesses seemed to influence their desired level of involvement: medium-large firms tended to prefer active involvement, whilst micro-small firms preferred passive/no involvement ($\nu = 1$, $\chi^2 = 3.229$, $P = 0.072$).

4.3.2 Business attitudes towards private sector investment in urban forests

Mandatory, voluntary or not at all

Ninety-percent of business respondents agreed with the principle of private sector contributions to urban trees given the decline in public sector funds for this resource. Indeed, 14 respondents made 24 comments about investing in the local environment being a moral duty; for example:

> *"Every business has a responsibility to its local area, as a local employer and part of the local community… I think we've all got a moral duty, a part to play." (BR10)*

Whilst 28 respondents made 123 positive comments about the possible introduction of an urban forest PES scheme in Southampton, a similar number also expressed reservations (104 comments from 27 respondents). For example, 6 respondents made 6 comments about the urban forest being the council's responsibility:

> *"The local council have limited funds so it slips off their list of priorities… I'm not sure that I agree with the principle that the private sector should then step in and cover the problem." (BR17)*

When asked which stakeholders should contribute to financing Southampton's urban trees, all respondents selected the local council, but only 63% thought that citizens should contribute. Whilst 67% thought that *all* businesses should contribute, 30% of respondents believed only those businesses causing pollution or loss of trees should contribute. Furthermore, ten respondents made 13 comments that polluters should pay *more* than other businesses, for example:

> *"Everybody [should contribute], but especially those causing pollution… if you're causing damage, you should be contributing more. It's just a matter of fairness." (BR15)*

None of these respondents identified themselves as a 'polluter' or a 'destroyer' of trees; they were shifting the responsibility to others. However, one other respondent said they would be motivated to contribute to right past wrongs:

> *"About 6 years ago we took out 3 or 4 trees to build a car park. Those trees were never replaced… so I think another reason [for contributing] is environmental damage caused by the business." (BR26)*

Just 27% of respondents would prefer mandatory (as opposed to voluntary) business contributions to Southampton's trees, with some stating it would be fairer (and cheaper) if everyone played a small part. Fourteen respondents made 19 comments in support of mandatory contributions (including five of those who voted for voluntary contributions). However, the majority of respondents (73%) thought that business contributions should be voluntary. Several of these reasoned that an environmental tax or similar mandatory payment would be unfair for small businesses, and might dissuade some from operating in the city (the payment amount was not discussed in the interviews). Overall, 24 respondents made 33 comments in support of voluntary contributions (including four of those who voted for mandatory contributions). Some respondents could see the benefits of both, for example:

"I think it should start on a voluntary basis, and then move to mandatory… after a period of consultation." (BR30)

In contrast, two respondents commented (n=2) that their business would be more inclined to volunteer their time, staff or equipment than money, for example:

"I don't think we would make a financial contribution. I can imagine us providing support perhaps through... some volunteer work." (BR14)

What and where to fund

When asked what the council should focus the additional funds from businesses on, respondents were overwhelmingly in favour of the money being spent on enhancing benefits rather than reducing nuisances. Regulating ES were particularly favoured, with 93% of respondents wishing additional funds to be channelled into improving air quality, and 83% into reducing local flood risk. The least favoured of all the tree benefits was reducing summer heat (43%); more commonly selected by business respondents concerned by future climate change, significant at the 5% level ($\nu = 1$, $\chi^2 = 4.904$, $P = 0.027$). Two respondents selected all benefits *except* reducing summer heat – one said:

"I'm not sure [planting trees] is a particularly efficient way of doing that. There's better ways, like air conditioning… I'm not sure I'd want [the council] to… plant trees just because of the heat… The other [benefits] are better, more tangible." (BR18)

Of the cultural benefits, improving the city's appearance was the most favoured, selected by 77% of respondents. In contrast, only 57% wanted the council to address tree root-induced damage to infrastructure (the highest ranking tree nuisance). The benefits and nuisances that businesses would prefer to fund are shown in Figure 4.3.

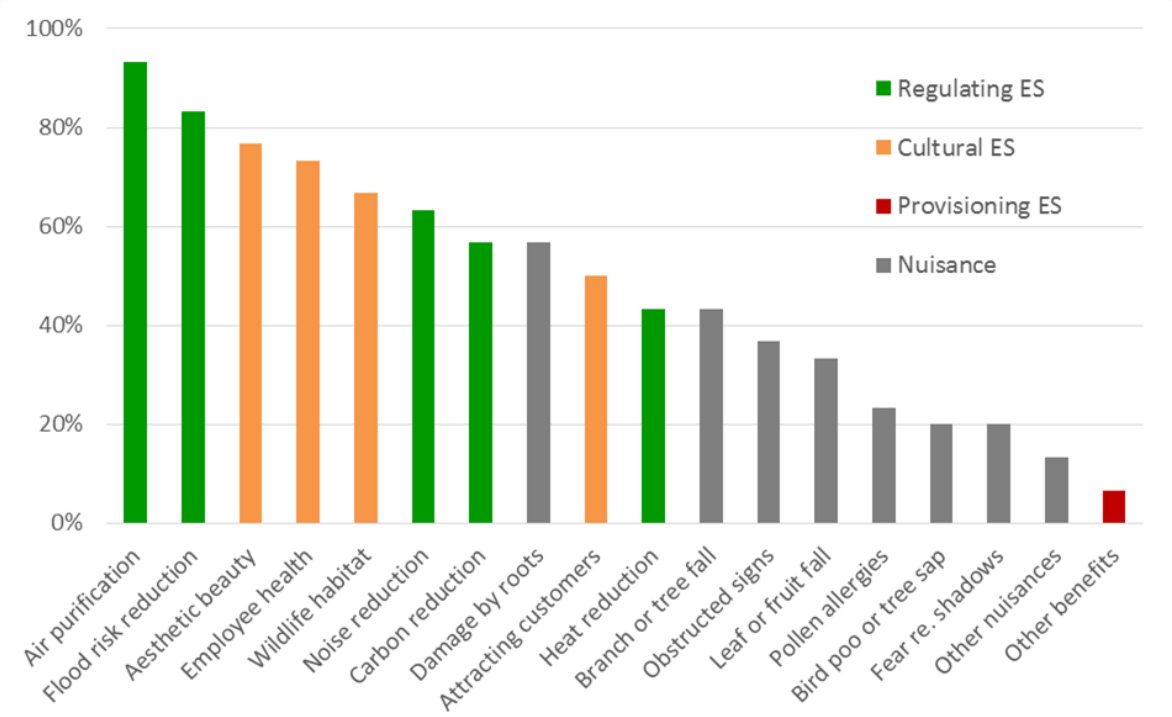


Figure 4.3: Proportion of businesses wanting funds spent on tree benefits and nuisances

Comparing Figure 4.1 with Figure 4.3 suggests that the ES that respondents would prefer to fund in Southampton are not necessarily those that are of most importance to their own business. This is likely due to pollution and flooding affecting the places where employees and customers of respondent businesses live. Three respondents (BR02, BR21 and BR29) specifically suggested that the PES scheme should be focused on enhancing the city's air quality given its recent 'Clean Air Zone' designation. In general, however, all respondents would be willing to fund the tree planting and maintenance activities knowing that a range (or bundle) of benefits would be provided.

Whilst 97% of respondents (all but BR09) would be willing to contribute to planting in areas currently devoid of trees, only 77% would be willing to contribute to enhanced maintenance of existing trees, as they perceived this to have less visual (and thus reputational) impact. Similarly, only 40% of respondents would be interested in contributing to the city's trees as a whole, whilst 60% would prefer to invest only in trees in the immediate vicinity of their business premises. This is because many respondents would require a tangible (and in some cases a financial) business benefit if an urban forest PES scheme were to receive their support (35 references from 19 respondents). For example:

> *"Financially it would be only in the immediate vicinity of your business premises... If you were doing it city-wide, you wouldn't necessarily – selfishly – see the benefits of it." (BR04)*

Sixteen respondents suggested that societal benefit would be a greater driver for them to invest than business benefit (24 references), whilst nine respondents commented that they would be looking for a win-win situation, for example:

> *"It can mean that you create initiatives where everyone wins – it's good for the local community because it brings more people to the Common[39] for example, and it also brings revenue to the business." (BR13)*

Reasons to invest

The majority of respondents (85%) would wish to publicise their contribution in order to promote their business both internally and externally. Sixteen respondents made 34 comments to this effect:

> *"You can have some crowing: 'I funded this!' If you do it and its voluntary there's a CSR benefit which is [useful for] marketing." (BR01)*
>
> *"Engaging staff in a team effort to do something good. It makes people feel nice and value the company." (BR16)*

Wanting publicity is also reflected in business motivations for investing in Southampton's trees, with 83% of respondents saying it would enhance the reputation of their organisation (see Figure 4.4). The second strongest motivating factor for contributing to an urban forest PES scheme would be to help meet corporate social responsibility (CSR) objectives – particularly for medium-large firms ($\nu = 1$, $\chi^2 = 3.416$, $P = 0.065$) and those affected by extreme weather events ($\nu = 1$, $\chi^2 = 3.601$, $P = 0.058$). Twenty respondents made 32 references to their proactive sustainability and/or CSR activities. Eleven respondents specified taking action to enhance the natural environment (e.g. habitat creation or funding local green infrastructure), though for some, CSR still has a more social focus. For example:

> *"We do CSR work, whether it's pulling Himalayan balsam or… doing some river restoration work." (BR19)*
>
> *"[Our CSR is] probably more community-focused rather than environmental." (BR28)*

[39] The Common is the largest contiguous greenspace (1.48 km^2) in Southampton, located to the north of the city centre. It contains a range of habitats, including woodland, parkland, rough grassland, ponds and wetlands, as well as formal recreation areas (Thomson, 1989).

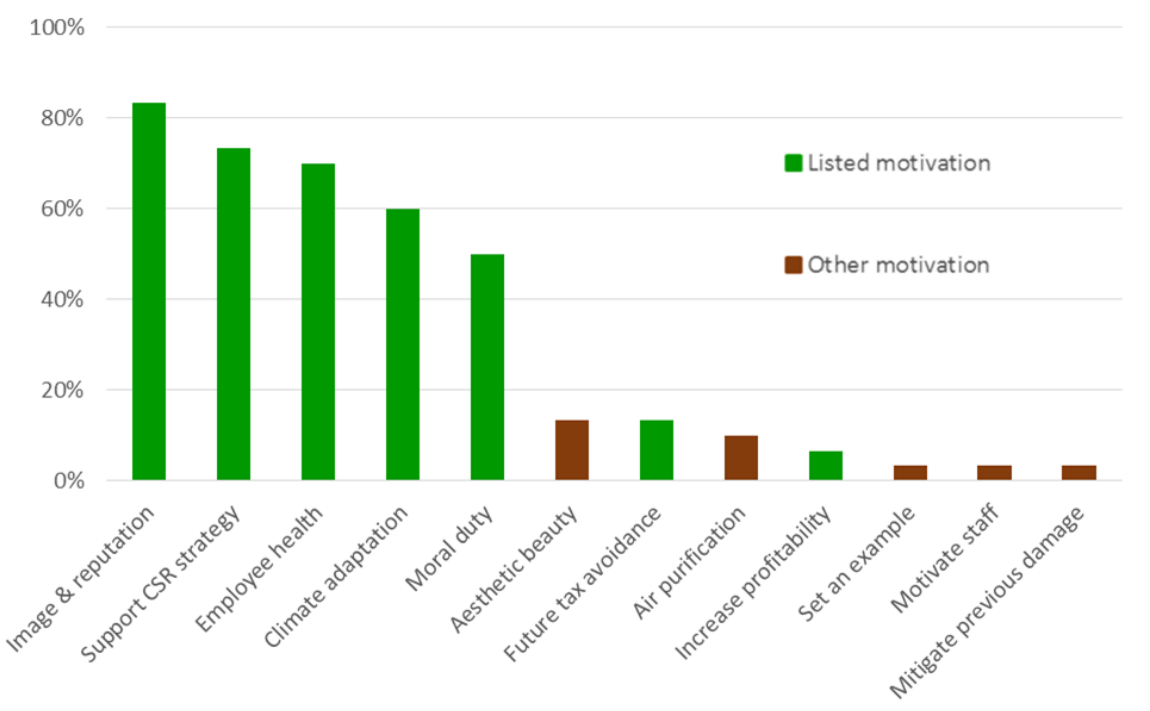


Figure 4.4: Proportion of businesses holding specific motivations for involvement in the proposed payments for ecosystem services scheme

The third strongest motivator for respondents was improving employees' health and wellbeing. Respondents with such motivations were more likely to want to enhance the maintenance of existing trees rather than just planting new ones, significant at the 5% level ($\nu = 1$, $\chi^2 = 5.111$, $P = 0.024$). They were also more likely to be located in a flood risk area ($\nu = 1$, $\chi^2 = 2.917$, $P = 0.088$). Ten respondents mentioned 'other' motivations – these included a more aesthetically pleasing environment in which to work (n=4), improving local air quality (n=3), setting an example to other businesses (n=1), motivating staff (n=1), and mitigating previous environmental damage (n=1).

4.3.3 Business preferences regarding the operation of an urban forest payments for ecosystem services scheme

Partnerships and payments

Almost all business respondents (94%) agreed a partnership between the public and private sectors could be made to work for funding Southampton's urban trees. Fifteen respondents made a total of 20 comments on the importance of businesses and the council working together if a PES scheme is to be successful, with nine respondents mentioning the need for a steering group to make the decisions. For example:

> *"Rather than saying 'here's a load of money, go and plant trees', it would be interesting to know, 'could we get involved [in planting and maintenance]?' …[That] would make the whole donation piece so much easier; otherwise it just looks like a tree tax." (BR25)*

Eight respondents commented that citizens should also be involved in the scheme – be that through financial contributions, volunteering their time, or even planting trees on their own land. For instance:

> *"Potentially citizens, because they're going to benefit too – particularly on the flooding front and air quality." (BR28)*

Many of the respondents made recommendations on how to ensure that an urban forest PES scheme is fair and smooth running, though opinions differed somewhat. For example, most respondents thought that, if mandatory, contributions should reflect either the size of the business (43%) or the impact the business has on the environment (also 43%), rather than a set rate for all businesses (7%). Large and small firms had differing opinions on the fairness of all firms paying the same versus larger firms paying more (though statistically there was no relationship between these variables). Comments included:

> *"You can't have a blanket rate payable by all businesses, otherwise [a multinational company] in Southampton would pay the same as me, and that's just stupid – it would put me out of business; I'd have to move." (BR23)*

> *"I know from the apprentice levy the feeling about different rates for micro, small, medium and large is quite painful. So given the [large] size of our organisation, they'd prefer the cheap option which is a blanket rate." (BR26)*

However, ten respondents suggested (on 15 occasions) that the scheme should be as simple as possible to avoid wasting time and money on complex calculations and controversial decisions – such as working out what a firm's environmental impact might be.

Information and monitoring

A total of 85 comments (from all respondents) were made about the level and type of information they would require before and during the implementation of a PES scheme. Firstly, assuming it were a voluntary scheme, a case for urban trees would need to be made to persuade businesses to invest (only two respondents were willing to invest without any further information). The majority (70%) of respondents would like to receive a business case (i.e. information on how their business is likely to benefit) before deciding whether or not to invest. A similar proportion (63%) would like an environmental case – particularly those motivated by improving employee health and wellbeing ($\nu = 1$, $\chi^2 = 3.308$, $P = 0.069$). Additional information – such as on similar schemes elsewhere, or a 'social case' for urban trees – would be required by 23% of respondents. For example:

> *"What you'd want is examples of three or four businesses that have had their businesses improved – and it's not necessarily financially, it could be the softer effects like wellbeing." (BR24)*

If contributing voluntarily, the majority of respondents (73%) would prefer to select from a list of costed projects to fund directly. Eleven respondents explained that this was because they would be able to see where their money is going. Those preferring to make a set annual payment instead were largely those who wanted contributions to be mandatory, significant at the 1% level ($v = 2$, $\chi^2 = 11.045$, $P = 0.004$).

For the implementation stage, 13 respondents said they would trust the council to manage the scheme appropriately, and so would not require monitoring. This would allow more money to be spent on the trees. For instance:

"I trust the city council to do what they're doing… I would save their resource." (BR13)

However, two-thirds of respondents would require the scheme to be monitored to make sure the council not only plants the trees (perhaps highlighted on a map), but ensures that they thrive. Twelve respondents made 16 comments on this, for example:

"If we've invested in them and then they're left on their own, we don't know whether they die or have been maintained. It would just be nice if someone came along and monitored them." (BR05)

Eight respondents went further and suggested (or implied) that the tree programme should be monitored to make sure that it is achieving the promised benefits. Two-thirds of respondents said the cost-effectiveness of the tree programme would influence their (continued) involvement. A total of 23 comments were made by 20 respondents on this subject, including:

"I'm looking to get the best bang for my buck." (BR08)

"I think if it became clear that the programme was deeply inefficient, then we'd certainly be less willing to contribute to it." (BR17)

In contrast, eight respondents commented that with an environmental scheme such as this, cost is less important than the wide array of benefits. Three respondents (BR02, BR15 and BR19) mentioned that trying to prove the delivery of benefits, or even to value the ES, is complex and subjective, making the cost-effectiveness hard to determine, and potentially making the scheme financially prohibitive. For example:

"It's hard to measure the money directly. I know there are some ecosystem services to put the value against, but it is rather subjective." (BR19)

4.4 Discussion

4.4.1 Business attitudes towards natural capital and ecosystem services

The literature suggests that business appreciation of the value of natural capital and ES provision is relatively poor. For example, PwC (2010) revealed that just 27% of the 1,198 surveyed CEOs

from around the world were concerned about the impact of biodiversity loss on their business growth prospects (the figure drops to 18% and 14% for CEOs based in Western Europe and North America respectively). The following year, 1,201 CEOs ranked 'protecting biodiversity and ecosystems' last out of ten public outcomes they would commit to over the next three years – a priority to only around 12% of respondents (PwC, 2011). As suggested by TEEB (2012), this may be because business leaders have limited understanding of the implications of biodiversity loss for their businesses, whilst ES provision tends to decline gradually and so goes unnoticed. Research by van den Burg and Bogaardt (2014) revealed that European businesses are not yet taking action to address impacts and dependencies on ES, due to uncertainty as to whether there is a business case for protecting ecosystems, and the extra burden associated with ES assessments. However, the launch of the Natural Capital Protocol[40] in 2016 is helping to address this. A minority of businesses are also now developing 'natural capital accounting' mechanisms in order to identify potential risks and opportunities related to natural capital (Binner *et al.*, 2017).

One of the benefits of natural capital that should be of interest to businesses is its ability to provide a nature-based solution to issues such as climatic and environmental change. PwC (2017) revealed that 50% of the 1,379 surveyed CEOs from around the world were either 'extremely' or 'somewhat' concerned about the impact of 'climate change and environmental damage' on their business growth prospects. The proportion of respondents concerned about the impact of future climate change on their business (particularly heatwaves and surface water flooding) was even higher in the present study, at 67%. However, despite these concerns, less than one-quarter of respondents in Southampton thought of trees as a nature-based solution to these issues. Again, this may be due to a lack of knowledge on ES – one respondent commented that they knew nothing of tree benefits prior to the interview, whilst several others were unsure how such benefits could be realised. Tree officers interviewed for Objective 1 similarly reported limited understanding of ES amongst private and public sector stakeholders.

Business preferences for urban forest ES specifically have largely been ignored in the literature. An exception is Wolf (2004a), whose research focuses on establishing the preferences of retail businesses and their customers across the United States for trees and the ES they provide. For the 165 business owners/managers responding to Wolf (2004a)'s multi-city survey, visual amenity was considered to be the most beneficial urban forest ES, supporting the findings of the present study (e.g. BR14). This was followed by heat regulation, nature connections, air purification and noise reduction (all rated as moderately beneficial or above) (Wolf, 2004a).

[40] The Natural Capital Protocol is a "decision making framework that enables organizations to identify, measure and value their direct and indirect impacts and dependencies on natural capital" (Natural Capital Coalition, n.d.).

In the present study, these ES were also important to business respondents, though addressing heat and nature connections were comparatively more important in the United States, and air quality and noise in the UK. This difference is perhaps influenced by Southampton's particularly poor air quality record and increasing pollution concerns recently, coupled with the higher average summer temperatures experienced in each of the US cities. Indeed, seven of the business respondents commented either that summer heat is not an issue for them, or that the ES of heat amelioration is less tangible or of lower priority than other ES (e.g. BR18). Paper 1 of this thesis similarly revealed a number of local authority tree officers to consider the ES of heat amelioration to be of low importance in the cool British climate.

A similar study has recently been undertaken with 141 business leaders in the UK city of Leeds – though investigating attitudes to green spaces rather than trees (Barker and Pina-Sánchez, 2019). The authors found the two main benefits of parks to be improved attractiveness of the area, and health and wellbeing of employees; each selected by around half of the business leaders. These results are also fairly similar to the Southampton study, however, they differ regarding attitudes towards stormwater attenuation, as just 15% of the Leeds respondents considered parks reducing the risk of flooding to be a primary benefit to their business (Barker and Pina-Sánchez, 2019).

Overall, it was found that business respondents rated tree benefits in Southampton as significantly more important than tree nuisances ($P<0.01$), in agreement with Wolf (2004a). This is in contrast to the perception of local authority tree officers in Britain that businesses have a negative attitude towards trees (as reported in Paper 1). Furthermore, a second study by Wolf (2004b), carried out with shoppers in a business district in Georgia in 2002, found the presence of trees to be particularly important to those who also worked in the district, suggesting "green streets may contribute to employee satisfaction" (p.339). This is supported by the Southampton study (e.g. BR24 and BR27), as well as others that suggest green space close to business premises can reduce stress and increase productivity. For example, Lottrup *et al.* (2015) found that employees of knowledge-based companies in Denmark whose view was dominated by trees reported higher job satisfaction and self-ratings of work performance. Gilchrist *et al.* (2015) similarly found both use and views of greenspace at UK science parks promoted employee wellbeing, with trees/woodland being preferred to grass and flowering plants.

In terms of business customers, Wolf (2004a) found their attitudes towards trees to be even more positive than that of business owners/managers. Wolf (2009) found that US consumers were willing to travel further and more often to retail areas with trees, spend more time there once they arrived, and "pay 9% more in small cities and 12% more in large cities for equivalent goods and services" (p.23). This contrasts with the perceptions of the business respondents in

Southampton (e.g. BR03), as just 20% thought trees were financially beneficial to their business (mainly through increasing staff productivity), and only one (BR29) mentioned that trees could increase sales revenue. Similarly, Barker and Pina-Sánchez (2019) revealed that only 9% of their surveyed business leaders in Leeds thought that parks improved their customer footfall. This may reflect the types of business included in the studies however, as only one of the respondents in the present study, and 5% of those in the Leeds study, represented the retail sector.

4.4.2 Business attitudes towards private sector investment in natural capital and ecosystem services

Overall, respondents in the present study were supportive of the private sector, as beneficiaries of ES, contributing to the proposed PES scheme. However, the majority thought it would be unfair and/or unpopular to make this a mandatory requirement due to the myriad of existing taxes and charges businesses face. In part this was simply a dislike for taxes, but some smaller businesses were concerned that a new eco-tax would put them out of business. In reality, any mandatory charge would be extremely low, and ideally ring-fenced for spending exclusively on tree planting that would have direct business benefits. It is therefore important that such messages are communicated to businesses to increase support for a mandatory scheme.

Just over half of the sample thought that a polluter pays system could also be appropriate – with seven suggesting that *only* polluters or developers should pay. In this context, PES could be designed as a policy mix, rather than a single instrument (Barton *et al.*, 2017). One solution could require mandatory contributions from polluters and developers, topped up by voluntary (or even in-kind) contributions from other businesses for CSR purposes (the latter being of interest to 73% of respondents). Alternatively, an entirely voluntary scheme could encourage contributions from those wishing to compensate for damage caused (as suggested by BR26) as a public relations exercise, in addition to a typical beneficiary pays approach. Either way, to increase voluntary contributions, it should be stressed that *all* businesses have a role to play in sustainability and environmental enhancement, as even simply driving to work can contribute to poor air quality and climate change.

There are very few studies investigating the willingness of businesses to invest in urban ES. A UK study into business preferences for investing in river-based ES in Manchester city centre found that visual amenity was of most interest to businesses – particularly those operating in the leisure, tourism and catering/hospitality industries (CLES and TWT, 2015). This supports the findings of the Southampton study (where three business respondents represented such industries) and those of Wolf (2004b, 2004a). However not one business was willing to pay to

enhance the river because they thought there would be no commercial benefit and they felt no moral duty to their local environment (CLES and TWT, 2015). This finding is in sharp contrast to the present study. Most recently, Barker and Pina-Sánchez (2019) ascertained the views of businesses in Leeds regarding charitable donations to parks and green spaces, though they did not link this to the park ES that businesses benefitted from. Of the 141 respondents, 16% had donated to conservation, environment and heritage causes in the previous 12 months; whilst 71% were in favour of business sponsorship of parks, and 74% supported the idea of contributions from property developers (Barker and Pina-Sánchez, 2019). These results are fairly similar to the present study.

Outside of the urban realm, Koellner *et al.* (2010) found 75% of business respondents willing to invest in tropical forest ES in Costa Rica – specifically watershed protection, carbon sequestration, biodiversity conservation, and scenic beauty. The study found no statistical difference in preferences based on business size or sector (industry, consumer and financial), but a statistically significant difference in opinion between the 31 international and 29 Costa Rican firms. The latter group were willing to invest in all four ES (especially watershed protection which benefitted many of them directly), but international firms were only willing to pay for the international benefit of carbon sequestration (Koellner *et al.*, 2010). Only five of the Southampton sample were international firms; these were not statistically different to the British firms in terms of ES funding preferences. In contrast to the present study, Koellner *et al.* (2010) found that most businesses considered biodiversity conservation and scenic beauty of forests to be of public rather than business concern. However, in an urban environment, these two services are arguably of greater importance (and more tangible) than watershed protection or carbon sequestration (e.g. see Dobbs *et al.*, 2011; Gómez-Baggethun and Barton, 2013).

Koellner *et al.* (2010) were surprised to find that intrinsic motivations had the largest influence on firms' willingness to invest in ES, closely followed by improving company image (the most important motivator in the Southampton study). A study published after the current paper has since had similar findings. Thompson (2018) found businesses involved as buyers in operational PES schemes in Thailand think of their involvement as a means of 'paying back'. However, Thompson (2018) implied that it was the ability to meet CSR obligations, gaining a social licence to operate, and favourable media attention that ensured businesses' continued involvement in the schemes.

Though only very few studies have investigated business interest in paying for ES, the environmental CSR literature provides additional insights into business involvement in paying for the enhancement or restoration of natural capital, and their motivations for this. Of 38 UK-based

multinational corporations investigated by Rondinelli and Berry (2000), the majority were found to engage in 'external' environmental practices for CSR purposes. These practices included employee participation in community environmental improvement activities; developing and preserving wildlife habitats on or near company premises; undertaking voluntary remediation of natural resources degraded by business operations; and preservation and replanting of forests. However, Rondinelli and Berry (2000) note that such practices are ad hoc, and represent only a tiny fraction of what is spent on 'internal' environmental practices such as reducing energy and resource use, recycling, and at-source pollution prevention measures. The situation is similar for the present study, as whilst 27% of the Southampton respondents have undertaken natural capital-enhancing CSR activities, 97% of them regularly engage in internal environmental practices.

This is likely because drivers of environmental CSR reported in the literature relate overwhelmingly to benefitting the company (e.g. improving company image, enhancing employee motivation, increasing sales), rather than to benefitting the environment or society (Weber, 2008; Meißner and Grote, 2015). The Southampton study supports this to some extent – for example, 60% of businesses would prefer any trees they fund to be planted near their premises to ensure that *they* will benefit. However this ignores the indirect business benefits of trees spread across the city: better air quality and aesthetics improve *living* and *commuting* environments, and thus health and productivity of staff; whilst enhancing the attractiveness of the city for *future* employees, investors and customers (Gore *et al.*, 2013). In contrast to this self-centred view, eight respondents commented that trees should be planted in areas of need and/or where they are best suited, to avoid benefitting only the richer areas. For example:

> *"If you look at the impoverished areas, they have no businesses but they could do with some trees." (BR15)*

Nevertheless, Koellner *et al.* (2010) and Meißner and Grote (2015) both felt that intrinsic motivations are rarely sufficient to invest in PES schemes, and so a business case (focusing on commercial benefit) would most likely be needed to persuade most firms to invest.

4.4.3 Business preferences regarding the operation of a payments for ecosystem services scheme

Due to the complexities of an urban environment and the large number of buyers (and potentially sellers) involved, Brewer *et al.* (2014) and CLES and TWT (2015) state that a very lengthy period of inter-organisational working will be required to establish a successful public-private PES partnership. Respondents in the present study were optimistic that such a partnership could work

for funding urban forests, though some wanted more involvement in decision-making than others, and only a minority showed interest in forming a steering group to help develop and monitor the tree planting and maintenance projects. Though there was no desire amongst respondents for an intermediary (such as a charity) to be involved, intermediaries are common in PES schemes and have been found to improve coordination and trust between ES buyers and sellers (Sattler *et al.*, 2013). Furthermore, with upfront canvassing, administration and transaction costs of PES schemes often (prohibitively) high, intermediaries can play a crucial role by reducing or meeting these costs (Vatn, 2010; Matzdorf *et al.*, 2013). TreeTime Edinburgh (2015), City Forest Credits (2017), NatureVest (2017), and CPRE Sussex (2019) are useful examples of intermediaries in an urban context.

From their experience with the Defra-funded PES pilot scheme in the urban area of Hull, MacGillivray and Wragg (2013) found it hard to find primary buyers willing to purchase ES, and suggested that secondary buyers (such as the local council or an NGO) will often be needed to act on their behalf (making contributions mandatory). This is perhaps due to concerns about free-riding, as found by Eves *et al.* (2015) during interviews with manufacturing companies in the UK, and suggested by business respondent BR06: *"if you make [the scheme] voluntary, only those that are like me will stick their hands in their pockets".*

To persuade businesses to contribute voluntarily, the council or intermediary would need to make a strong case for investment, perhaps explaining how businesses could improve their reputation, meet CSR objectives, and improve employee wellbeing (thus allaying fears over free-riders who would miss out on such benefits). Bennett *et al.* (2014) in the United States found that utility companies' interest in water-based PES schemes would be enhanced by demonstration of financial benefits, whilst Eves *et al.* (2015) recommended communicating the key successes from other PES schemes with target audiences. Making a business case (incorporating environmental and social aspects) to company owners and managers is key – not just for raising funds, but for spreading the message of social and environmental sustainability more widely amongst this influential community. Knowledge exchange between the business sector and universities/ governments/NGOs regarding environmental issues and opportunities has increased in recent decades due to institutional pressures and access to environmental knowledge transfer networks, but remains voluntary and ad hoc (Wassmer *et al.*, 2014; Stadtler and Lin, 2017). The involvement of an intermediary to help with knowledge exchange may be useful in this context (Schomers *et al.*, 2015).

There was no requirement amongst respondents for business-funded projects to be distinguished from the council's regular activities (i.e. ensuring additionality) – likely due to few UK local

authorities still having budgets for tree planting (as found through Objective 1). Nevertheless, respondents preferred the idea of planting new trees over maintaining existing trees, whilst BR01 and BR17 were concerned that businesses should not be picking up the slack left by public sector budget cuts. In terms of conditionality, Koellner *et al.* (2010) found that the existence of an independent verifier ensuring that the service paid for is in fact delivered, was important for all firms (i.e. ensuring output conditionality). This finding was not supported by the Southampton study – the majority of respondents would be content with a record of tree planting (representing input conditionality). Input conditionality also seems to be sufficient for the UK Peatland Code; though the carbon sequestration benefits of peatland restoration are quantified and verified, this is generally done through vegetation proxies. Furthermore, in the Peatland Code PES pilot study, Reed *et al.* (2013) (p.28) found that potential funders "would be happy with broad assurances based on their trust in the bodies delivering restoration, and did not require rigorous monitoring of co-benefits" due to the likely expense. However, a minority of the Southampton respondents would like to 'see the benefits' being delivered in order to justify their continued involvement. Tools such as i-Tree Eco or Treezilla[41] might be useful in this regard.

Cost-effectiveness (i.e. delivering benefits at the lowest cost) has been identified as one of three main characteristics of PES success, along with environmental effectiveness and achieving equity (Jack *et al.*, 2008). The majority of the business respondents deemed cost-effectiveness of the PES scheme to be important, with one (BR23) expressing a concern that councils do not always spend money wisely. However, Kroeger (2013) argues that cost-effectiveness (and therefore environmental effectiveness) of PES schemes cannot be determined because, at best, they account only for the 'flow' of ES provided (or at worst, land-use changes assumed to provide such ES); not the 'value' of the realised benefits. In a review of 25 PES schemes from across the world, Hejnowicz *et al.* (2014) found that 84% of these measured inputs (i.e. land-use changes) rather than outputs (i.e. actual ES provision), with only tenuous links generally made between the two. However, as noted by Lima *et al.* (2017) and respondents to the present study, there is uncertainty around the delivery of benefits from PES schemes, and trying to prove and/or value delivery can increase transaction costs. In terms of distributive equity, BR01 and BR15 suggested the council might need to prioritise disadvantaged areas to avoid businesses only paying for tree planting in their own wealthy neighbourhoods; whilst also avoiding gentrification of impoverished areas.

[41] Treezilla is an online platform whereby trees in the UK are mapped (by anybody), and the value of the ES they provide is displayed (The Open University, no date).

4.4.4 Study limitations

There are a number of limitations to this study: problems in recruiting respondents resulted in a small sample size, contributing to a lack of significant statistical results. Almost half of the businesses were located outside the target city, generally in less urbanised areas, whilst the business size segmentation of the sample also differed from the known enterprise demographics, with micro businesses particularly lacking. Future studies should aim for a much larger and more representative sample, with more emphasis placed on engaging with smaller businesses. Identifying the saliency of the significant and non-significant relationships reported here (via further studies) will be important for the marketing of urban forest PES schemes. An additional issue is potential non-response bias: 70% of those contacted directly did not take part, whilst very few businesses responded to the advertising of the study in local business newsletters; perhaps the subject-matter was not perceived as sufficiently salient to respond. However, it is also possible that non-respondents may have had less positive – even negative – attitudes towards (paying for) trees. Such views could undermine the feasibility of an urban forest PES scheme. Future studies should seek to identify these, for example by randomised visits or phone calls to non-respondents.

4.5 Conclusions

The paper published for Objective 2 of this thesis makes an important contribution to the sparse literature on business attitudes towards trees and ES, and funding these. It also facilitates the piloting of business-funded, urban PES schemes as a means of improving city image, quality of life, and adaptation to climate change in cities across Britain and elsewhere; though additional research on the subject would be advantageous to any such pilot.[42]

In the self-selecting sample, business attitudes towards trees were positive, with benefits mostly prioritised over nuisances. Moreover, climate change was a concern to many respondents. Business respondents were also positive towards the possibility of private sector investment in urban forests, with half even suggesting it to be their moral duty to do so. However, intrinsic motivations are rarely enough on their own. Indeed, many businesses were concerned about the financial burden of an 'extra tax', and so would prefer contributions to be voluntary. Whilst this

[42] Since the publication of this paper, Krause and Matzdorf (2019) have conducted further research on the subject, interviewing 26 businesses in Germany regarding their potential involvement in an online, voluntary PES scheme covering a variety of conservation projects nationwide. Krause and Matzdorf (2019) found reputation/brand value and intrinsic/moral concerns to be the primary motivators, though only 46% of the sample were interested in purchasing PES credits. Investment preferences included: close proximity to company headquarters; flexibility in the timing and size of contributions; and quantification of ES provision – particularly for biodiversity, climate and water-related ES.

presents a risk that businesses will support a PES scheme in theory, but then opt out in practice, this does not appear to be the reason for preferring a voluntary scheme. By far the greatest motivation for involvement in an urban forest PES scheme in Southampton was the commercial benefits it would bring to the company through enhancing their image and reputation – something that can only be achieved through a voluntary scheme. Consequently, businesses would prefer to choose from a list of location-specific projects to fund directly, as this would enable them to benefit both directly (e.g. from improved employee health), and indirectly (e.g. improving their reputation via marketing and CSR).

Regarding the operation of an urban forest PES scheme, this would ideally be through a partnership between the public and private sectors (potentially incorporating citizens). Respondents were most interested in making payments towards enhancing air quality, reducing flood risk, and improving the appearance of the city, though there was little interest in paying for heat amelioration despite heat-event experiences and climate change projections. However, they would first require the council (or an intermediary) to set out how their business and local area would be likely to benefit from the scheme, drawing on the key successes and lessons learnt from similar schemes elsewhere. Most respondents also considered transparency, input-based conditionality, and cost-effectiveness of the scheme to be necessary.

Based on these results, it is considered that business-funded PES schemes have potential as a means of funding improved ES delivery from urban forests. However, if sufficient businesses are to contribute to make a voluntary scheme viable, then a strong, concise case for investment is needed. This should incorporate social, environmental and business aspects, supported by quantified and, where possible, valued ES data, and with real examples of business benefits. Should future studies support these findings, it is recommend that pilot urban forest PES schemes should be designed and evaluated – perhaps focusing initially on city centres or business districts – following steps outlined by authors such as Sattler and Matzdorf (2013).

However, it is not only businesses that benefit from urban forest ES; citizens do too. Respondents to the interviews conducted for Objective 1 and Objective 2 were both aware of this. Indeed, 67% of interviewed tree officers, and 63% of the business representatives thought citizens should be contributing financially to the planting and maintenance of urban trees. Objective 3 therefore seeks to determine if citizens might also be willing to pay for urban forest ES provision via a PES scheme.

Chapter 5 Citizen willingness-to-pay for an urban forest payments for ecosystem services scheme with uncertain outcomes

This chapter will be split into two separate papers for submission to two different journals during 2020.

5.1 Introduction

Payments for ecosystem services (PES) schemes typically sell only a single ES (e.g. enhanced water quality), however, government-funded schemes are increasingly selling multiple ES together in order to optimise overall ES provision (Kemkes *et al.*, 2010; Sattler *et al.*, 2013). ES can be bundled together as one package; sold individually in layers/stacks (where each buyer can choose the ones they prefer); or payments for one key ES lead to the production of additional services for free, known as piggy-backing (Wertz-Kanounnikoff *et al.*, 2011). A survey of UK environmental professionals revealed mixed views on whether PES schemes focused on payments for single or bundled ES are most appropriate, leading Waylen and Martin-Ortega (2018) to call for more research on the subject.

Ascertaining willingness-to-pay (WTP) for individual ES is a common approach for stated preference studies of forest ecosystems (e.g. Brey *et al.*, 2007; Gatto *et al.*, 2014; Roesch-McNally and Rabotyagov, 2016). However there appears to be a gap in the literature regarding the valuation of individual urban forest ES, with only two studies found to do this (Morawetz and Koemle, 2017; Soto *et al.*, 2018). Instead, urban forest stated preference studies typically ascertain WTP for protection or expansion of urban forests in order to secure enhanced provision of a generic bundle of ES (see sub-section 2.3.2). This is despite the fact that citizens hold different preferences for different urban forest ES, with aesthetic beauty, heat amelioration and air purification found to be especially important (see review of citizen preference studies presented in sub-section 2.3.1).

Furthermore, most studies that investigate WTP for environmental schemes assume that respondents make choices based on scenario and attribute information alone, taking this information as fact. However, the outcomes of environmental programmes are uncertain, and failing to disclose this is already resulting in a loss of trust and support from citizens and other beneficiaries as operational schemes fail to deliver the promised benefits (Moffat, 2016; Lima *et*

al., 2017). Consequently, a number of authors have called for objective information on outcome uncertainty to be incorporated into WTP studies for environmental programmes (e.g. Wielgus *et al.*, 2009; Glenk *et al.*, 2014; Lundhede *et al.*, 2015). A number of studies have attempted this, relating outcome uncertainty to specific attributes, or specific choice tasks, or the scenario as a whole for specific respondents. A review of 20 such studies (see sub-section 2.3.3) found 75% to conclude that respondents have higher WTP (and/or are more likely to pay) for more certain outcomes. For example, for an increase in the probability of success, people were willing to pay more for programmes delivering carbon sequestration (Glenk and Colombo, 2011) and heat amelioration (Akter *et al.*, 2012).

However, both Wielgus *et al.* (2009) and Glenk and Colombo (2011) postulated that surveys containing objective information on outcome uncertainty would return *higher* WTP for environmental programmes than would surveys without, due to this information adding to the credibility of the scenarios. Presumably, these authors thought that respondents would doubt the realism of a programme with guaranteed environmental outcomes, and thus take into consideration their own, differing, subjective beliefs about the likely outcomes (Burghart *et al.*, 2007; Nguyen *et al.*, 2010). Subjective beliefs being prioritised over conflicting objective information in decision-making is an example of 'disconfirmation bias', whereby people readily accept confirmatory arguments, but actively reject opposing ones (Taber and Lodge, 2006). Unfortunately, neither Wielgus *et al.* (2009) nor Glenk and Colombo (2011) collected respondent perceptions about the provision of objective certainty information, or crucially, respondents' subjective uncertainty surrounding environmental programmes, so their postulation could not be tested.

Three stated preference studies have since collected respondents' subjective beliefs, however only Lundhede *et al.* (2015) linked these with objective uncertainty information. These authors argued that providing information on outcome uncertainty does not mean that people will base their choices on it; eliciting information on respondents' subjective beliefs about a policy is also needed to explain choices, and to reduce the random component of utility (Lundhede *et al.*, 2015). The key result of Lundhede *et al.* (2015) was that WTP for a conservation policy with objectively uncertain outcomes was significantly lower for a priori 'doubters' (i.e. respondents who, before being presented with objective uncertainty information, rated the likely policy outcome as rather or very uncertain) than for a priori 'trusters' (i.e. those who rated the likely policy outcome as rather or very *certain*). However, determining whether respondents weight the objective information with their prior beliefs would have required further modelling to ascertain how trusters and doubters each reacted to certain and uncertain outcomes. Furthermore, posterior beliefs should have been obtained to identify individual reactions to cognitive

dissonance (i.e. whether respondents adjusted their beliefs following receipt of objective uncertainty information that conflicted with their prior beliefs) (Akerlof and Dickens, 1982).

The purpose of this part of the thesis is to determine how citizen WTP for provision of individual urban forest ES (via a PES scheme), is affected by public preferences and values, and the objective and subjective uncertainty surrounding ES delivery.[43] To this end, four research questions were posed:

1. To what extent are citizens willing to invest in a PES scheme that focuses on urban forest-based air purification, stormwater attenuation, and aesthetic enhancement?
2. To what extent is citizen WTP for air purification, stormwater attenuation and the PES scheme as a whole, affected by the objective uncertainty associated with delivery of these urban ES?
3. Is citizen WTP for air purification and stormwater attenuation, and for improving objective certainty, affected by the subjective uncertainty people associate with delivery of these urban ES?
4. To what extent is citizen WTP for a PES scheme different for respondents experiencing either objective uncertainty over ES outcomes, subjective uncertainty over ES outcomes, or both objective and subjective uncertainty together, compared to respondents who experience no outcome uncertainty?

5.2 Materials and methods

A discrete choice experiment (DCE) was carried out with residents of Southampton via an online survey in September 2018. A DCE is a stated preference technique, commonly used for assessing people's WTP for non-market environmental goods and services. It does so via a series of questions that require respondents to state their preferences for these goods in a hypothetical market setting. By describing the environmental good in terms of its characteristics (or 'attributes') and the different levels that these can take, it is possible to determine how the 'utility' gained from the good changes as one or more of the good's attributes are varied (Lancaster, 1966; Pearce *et al.*, 2002). Survey respondents are typically presented with a baseline scenario corresponding to the status quo (SQ) and two alternative policy options in which the levels of attributes are changed. Respondents are then required to state their preferred option between the different alternatives – this is known as a choice task, of which there will be several.

[43] Note that only outcome uncertainty is addressed by this paper. It does not address 'preference' or 'decision' uncertainty, i.e. the uncertainty that respondents may experience when making choices (Dekker *et al.*, 2016).

Each choice the respondents make will require them to make a trade-off between the attributes. By including a monetary indicator (a price, charge or tax) as an attribute of each alternative, WTP for the other attributes can be inferred by the choice of alternative made. DCEs are underpinned by Lancaster's theory of consumer choice, and are modelled based on random utility theory (Lancaster, 1966; McFadden, 1968; Pearce *et al.*, 2002). This section first discusses the theoretical underpinnings of DCEs (sub-section 5.2.1), and the process of choice modelling (sub-section 5.2.2). It then sets out the process of designing and administering the DCE and wider survey (sub-section 5.2.3), followed by the specific hypotheses that were tested (sub-section 5.2.4), and finally details on administering the DCE (sub-section 5.2.5).

5.2.1 Economic theory underpinning discrete choice experiments

Classic consumer choice theory assumes that rational individuals choose the goods that bring them most utility – subject to the financial constraints of the price of the goods and the individual's income (Hicks, 1939; Samuelson, 1947). This behavioural rule is known as 'constrained utility maximisation'. Lancaster (1966) posited that the utility gained from a particular good is a function of its underlying attributes. Lancaster's theory of consumer choice therefore modifies the standard goods of consumer choice theory with bundles of attributes. The utility that goods or attributes provide to people cannot be observed directly, but can be inferred by analysing the choices that people make, which in turn depend on their preferences. In this framework, a number of assumptions about people's preferences are made to enable the analysis of choices, known as preference axioms (von Neumann and Morgenstern, 1947; Hausman, 2011; Snyder and Nicholson, 2012):

a) Completeness – People have well-defined preferences over alternative bundles of goods: either X is preferred to Y, Y is preferred to X, or they are indifferent between X and Y (i.e. $X \geq Y$ or $Y \geq X$). They cannot prefer X to Y and at the same time Y to X.
b) Transitivity – People have consistent preferences over alternative bundles of goods, meaning that if they prefer X to Y, and Y to Z (i.e. $X \geq Y$, and $Y \geq Z$), then they must also prefer X to Z (i.e. $X \geq Z$). This means that, assuming that consumers have full (understanding of) information relating to their choice decision, all bundles of goods can be placed in order of preference, from best to worst.

These two axioms suggest a rational consumer, but to represent their preferences through a utility function, e.g. U(X,Y,Z), a third preference axiom is required:

c) Continuity – If a person prefers X to Y, then bundles close to X must also be preferred to Y. Similarly, if a person hold the preference $X \geq Y \geq Z$, then there exists a particular

combination of bundles X and Z that will be equally attractive as bundle Y, e.g. X/2 + Z/2 = Y. This continuity in the utility function means that consumer responses to marginal changes in prices or income can be analysed.

Once the continuous utility function is defined, three more preference axioms are required to explain how a consumer arrives at a choice outcome:

d) Monotonicity – People prefer more to less, meaning that bundle X, containing one unit more of a good than bundle Y, is strictly preferred to Y.
e) Convexity – People prefer bundles containing a well-balanced mix of goods to those containing only one type of good, and so require increasingly larger amounts of one good to compensate for successive unit losses of the other.
f) Choice consistency – Among the alternatives they believe to be available, a consumer will always choose their preferred bundle (via a conscious or unconscious process of utility maximisation), subject to a budget constraint.

As pointed out by Hausman (2011), the literature contains counter-examples to all of the preference axioms – see McFadden (1999) for a critique of economic rationality. The axioms should therefore be considered as approximations of reality (Hausman, 2011).

Expected utility theory

In uncertain choice contexts, consumer choice theory often fails to explain empirical observations. This is because a rational consumer is expected to choose the outcome with the highest expected value (i.e. the probability of occurrence multiplied by the pay-out). However, this ignores the possibility that people may be averse to risk and therefore prefer a 'sure thing', even if it has a lower expected value than a riskier gamble. For example, a guaranteed pay-out of £50 may be preferred to a gamble with a 67% chance of winning £100, and a 33% chance of winning nothing. Expected utility theory (EUT), coined by Bernoulli (1738) and developed further by von Neumann and Morgenstern (1947), concerns people's preferences with regard to choices that have uncertain outcomes. EUT states that, when there is uncertainty about the outcome of an action, a rational consumer will choose the action with the highest 'expected utility' (or psychological value) instead (i.e. the probability of occurrence multiplied by the subjective utility). The possibility that people may be averse to risk is therefore taken into account.

Wibbenmeyer *et al.* (2013) posited that the majority of economic studies of risk preferences and choices under uncertainty rely on an expected utility model, in which people are risk averse and preferences over outcomes are nonlinear. However, behaviour that is inconsistent with EUT is also well documented, and led to the development of prospect theory (Kahneman and Tversky,

1979). Whilst people tend to be risk averse when making decisions regarding potential gains, in the case of potential losses, prospect theory posits that people are risk-seeking. Prospect theory also allows preferences for risky decisions to be nonlinear in probabilities as well as outcomes, i.e. accounting for the possibility that people overweight very small probabilities. As described in sub-section 5.2.3, this study concerns only gains with mid-high probabilities; EUT is therefore sufficient. The application of EUT in the context of DCEs is described below.

5.2.2 Choice modelling approach

The theoretical framework for analysing choice data is the random utility model (McFadden, 1968). This assumes that rational people make choices based on their preferences and a desire to maximise utility, with variations to this caused by 'random' (i.e. unobserved) factors (Hensher *et al.*, 2005). The information available to the analyst observing the decision maker's choice thus limits them to a 'modified' behavioural choice rule, known as 'random utility maximisation' (Hensher *et al.*, 2005). The random utility function is set out in the form:

$$U_{int} = \alpha_{int} + \beta_{zn} Z_{int} + \mathcal{E}_{int} \qquad (1)$$

The observable (deterministic) part of utility is measured explicitly in the choice model, and can be split into two components: α_{in} is the alternative specific constant (ASC) capturing the preference of respondent (n) for a policy-based alternative (i) over the status quo (in choice situation t). Individual choice behaviour is typically modelled through a utility function that is linear and additive in all the attributes – as such, $\beta_{zn}Z_{int}$ reflects the preference parameters (β) related to the attributes (z) in vector Z, i.e. Z_{int} is a vector of z observed attributes. Finally, $\mathcal{E}_{int}$ is the error term, representing the unobserved (random) utility. The error term comprises a set of random variables that are assumed to be 'independent and identically distributed' across individuals and alternatives (following a Type I extreme value Gumbel distribution) (Manski, 1977).

The random utility models most commonly used in DCEs are the multinomial logit (MNL) model; the random parameter logit (RPL) model; and the latent class logit model (Holmes *et al.*, 2017). An advantage of the RPL model is that it takes preference heterogeneity into account by assuming preferences vary across individuals – in a continuous fashion, with a specific density function (McFadden and Train, 2000; Greene and Hensher, 2003; Scarpa and Thiene, 2005). The RPL model also relaxes the unrealistic 'independence of irrelevant alternatives' (IIA) assumption of the MNL model, as it has often been shown that the probability of choosing between two options changes when a third option is introduced (Train, 2009). Furthermore, by using conditional distributions for each random coefficient, based on records of the choices made by each individual in the

choice tasks, it is possible to infer each individual's most likely location along the distribution (Hess, 2010). If the variance of the individual-level conditional means (the 'between variation') captures a sufficiently large share of the total variation in a coefficient (i.e. compared to the 'within variation' around these means), then posterior analysis can be used to regress the conditional β estimates for each individual onto their socio-demographic/attitudinal characteristics (Train, 2009; Hess, 2010).

The sequence of choices made by each individual can be explained only up to the probability, or likelihood, of the individual making the sequence of choices they were actually observed to make (Hensher *et al.*, 2005; Train, 2009). RPL models are estimated by finding values for the β parameters that make the observed choices the most likely (given the model used), using maximum likelihood estimation. This cannot be evaluated analytically, and requires a simulation procedure. Full details on estimating RPL models are provided by Train (2009).

Finally, by including price as one of the attributes in the DCE, it is possible to calculate the monetary value of the marginal change in utility of the good when one of the good's other attributes is changed (Carson and Czajkowski, 2014). This marginal WTP is calculated for each attribute by dividing its coefficient by the negative of the coefficient of the price attribute:

$$WTP = \beta_z \,/\, -\beta_p \qquad (2)$$

To account for the standard errors associated with the WTP ratio of β parameters (especially random parameters), marginal WTP can be estimated using a number of different methods, of which the Delta method (Oehlert, 1992) and the Krinsky and Robb (1986) bootstrapping procedure are the most commonly used. These methods provide a confidence interval (e.g. 95%) around a mean WTP value.

Modelling choices under outcome uncertainty

The main theory that underpins the incorporation of outcome uncertainty (based on known objective probabilities) in DCEs is the random utility model, adapted to allow for EUT-based risk preferences. This results in what Roberts *et al.* (2008) and Akter *et al.* (2012) refer to as a 'random expected utility model', which incorporates risk-based interaction terms within the utility function to represent outcomes weighted by the likelihood of occurrence. An example of a risk-based interaction term is shown below, where the variable 'Certainty' reflects different levels of risk or probability of the outcome occurring:

$$U_{int} = \alpha_{int} + \beta_1 Outcome * Certainty + \mathcal{E}_{int} \qquad (3)$$

The majority of the studies reviewed in sub-section 2.3.3 used this EUT-adapted random utility model. However, three of the reviewed studies also investigated whether (un)certainty has direct

(dis)utility on respondents, independent of any of the other attributes (Glenk and Colombo, 2013; Lundhede *et al.*, 2015; Rolfe and Windle, 2015).[44] In this 'direct utility model', a variable for (un)certainty is incorporated directly into the utility function instead of as an interaction term:

$$U_{int} = \alpha_{int} + \beta_1 Outcome + \beta_2 Certainty + \mathcal{E}_{int} \quad (4)$$

There is no theory per se underpinning the direct utility model; however, empirical support for direct aversion to risk is provided by Gneezy and Potters (1997) and Simonsohn (2009). These studies showed that the 'uncertainty effect', i.e. that people are willing to pay less, on average, for a binary lottery than they are willing to pay for its worst outcome, is caused by uncertainty entering directly into people's utility function. Of the studies reviewed in sub-section 2.3.3, Glenk and Colombo (2013) found that their direct utility model fit their data better than their EUT model, suggesting that respondents separately evaluated the risk of the policy failing, and the environmental outcome in case of policy success. Lundhede *et al.* (2015) also found strong statistical support for their direct utility model, with the independent parameter for outcome uncertainty being significant and negative. Indeed, when uncertainty is included as a separate attribute in the choice task (as it is in the present study) it is likely that some respondents will evaluate it separately as a simple heuristic to reduce the cognitive burden of the task (Veronesi *et al.*, 2014).

Dealing with differences in scale between samples

Around half of the studies reviewed in sub-section 2.3.3 used either a split-sample approach or a before-after approach to test the effect of uncertainty on WTP, resulting in data from a certain control group and additional data from an uncertain treatment group. Because the treatment and control groups are presented with different information, it is possible that the 'randomness' of the choices respondents in the two groups make (i.e. the variance of the error term) will be different (Swait and Louviere, 1993). Studies usually get around this by modelling the choices from the different datasets separately, and comparing the mean WTP values instead of the β estimates (Czajkowski *et al.*, 2016). This is because the sample-specific scale parameter drops out when WTP is calculated, making WTP estimates from different samples comparable. However, if the datasets are to be *combined* for analysis it is necessary to first identify whether the scale parameters (σ , i.e. the inverse of the variance of the error term) differ between them, and if so, to account for this in parameter estimates (Swait and Louviere, 1993).

[44] Rolfe and Windle (2015) additionally combined EUT with direct utility, by modelling a 'direct-partial expected utility model' of the form: $U_{int} = \alpha_{int} + \beta_1 \text{Outcome} + \beta_2 \text{Outcome} * Certainty + \beta_3 Certainty + \mathcal{E}_{int}$.

As it is not possible to calculate absolute values of scale for any dataset due to the confounding with preference parameters, the scale parameter for the control group can be normalised to the value of 1 (Hess and Rose, 2012). The scale parameter for the treatment group is then estimated *relative* to the normalised scale parameter of the control group. If the scale parameters for the two datasets are different, this is accounted for when merging the datasets by multiplying all of the model parameters (including the ASC) by the relevant scale parameter (σ_R) (Hess *et al.*, 2008; Hess and Train, 2017). This approach was used recently by Faccioli *et al.* (2018), and is modelled as follows:

$$U_{int} = \sigma_R(\alpha_{int} + \beta_{zn}Z_{int}) + \mathcal{E}_{int} \quad (5)$$

Where:

$$\sigma_R = \sigma_C{*}\gamma_{Control} + \sigma_T{*}\gamma_{Treatment} \quad (6)$$

Here, σ_C is the normalised parameter for scale for the (certain) control group (i.e. a constant of 1); $\gamma_{Control}$ is a dummy variable accounting for respondents in the control group (i.e. it takes the value 1 for the control, and 0 for the treatment); σ_T represents the effect of the (uncertain) treatment on scale (to be estimated by the model); and $\gamma_{Treatment}$ is a dummy variable accounting for respondents in the treatment group (taking the value 1 for the treatment, and 0 for the control). With scale normalised to 1 for the control group, a higher (lower) value for σ_T would mean that respondents in the treatment group make less (more) random choices than those in the control group. However, it should be noted that this approach is limited by accounting only for the difference in the scale mean between the control and treatment groups. It does not account for the potential difference in the scale variance between the control and treatment groups; or for scale heterogeneity at individual respondent level (Hess and Train, 2017).

5.2.3 Choice experiment design

5.2.3.1 The questionnaire

In order to identify the effect on WTP of providing information on outcome uncertainty as opposed to implying that environmental outcomes are certain, it was necessary to have two different versions of the questionnaire. The 'certain' version (respondents of which represent the control group) implies full certainty around delivery of ES. In contrast, the 'uncertain' version of the questionnaire (representing the treatment) contains an attribute specifying varying levels of objective certainty. The full questionnaire of the uncertain version is provided at **Appendix D**; the different sections of the questionnaire covered the following topics:

a) Attitudes towards the benefits and nuisances associated with street trees;

b) Attitudes towards air pollution and surface water flooding problems and solutions in Southampton, including prior (subjective) beliefs[45] regarding the nature-based solution of tree planting;

c) Uncertain version only: probability in the context of environmental outcomes was carefully explained in order to limit any increase in the randomness of choices of this group, with a question[46] used to test comprehension;

d) Explanation of the proposed citizen-funded street tree planting programme, including the attributes (the selection and design of which are described below, with attribute levels set out in Table 5.1);

e) The choice tasks (see Figure 5.1 on page 142 for an example choice task);

f) Reasons for (un)willingness to pay, consequentiality of the programme, and posterior beliefs regarding the delivery of air quality and flood reduction benefits; and

g) Socio-demographic data.

Table 5.1: Attributes and their levels for the 'uncertain' version of the questionnaire

Attribute	Levels	Modelled variable
Yearly reduction in pollution-related deaths	No reduction (115 pollution-related deaths) (SQ) 1 fewer pollution-related death 4 fewer pollution-related deaths 7 fewer pollution-related deaths	AirQ – a continuous variable representing 1-7 fewer pollution-related deaths
Reduction in residential flood risk	No reduction (10,000 properties at risk of flooding) (SQ) 100 fewer properties at risk of flooding 300 fewer properties at risk of flooding 500 fewer properties at risk of flooding	Flood – a continuous variable representing 100-500 fewer properties at risk of flooding
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	0% (no tree programme means no reductions) (SQ) 40% chance of reductions in deaths and flood risk occurring 70% chance of reductions in deaths and flood risk occurring 100% chance of reductions in deaths and flood risk occurring	ObjCert – a continuous variable representing a 40-100% chance of reductions in deaths and flood risk occurring
Change to appearance of Southampton's streets	No change (SQ) Small trees (of one species) planted Large trees (of one species) planted Mixed trees (of varying sizes and species) planted	AppLarge – a dummy variable representing large trees AppMixed – a dummy variable representing mixed trees
Payment by your household to support new street tree planting in the city	£0 (SQ) £24 per year (£2 per month) £60 per year (£5 per month) £96 per year (£8 per month) £132 per year (£11 per month) £168 per year (£14 per month)	Payment – a continuous variable representing household payments of £24-£168 per year

[45] Subjective beliefs were obtained by asking the question, "on a scale of 0 (not at all confident) to 10 (very confident), how confident are you that planting new trees on Southampton's streets would reduce air pollution in the city?" A second question was asked regarding respondents' confidence that trees would 'reduce surface water flooding'.

[46] The question was as follows: "Which of the following three cities is least likely to rain tomorrow? City A: 40% chance of rain tomorrow; City B: 70% chance of rain tomorrow; or City C: 10% chance of rain tomorrow."

To avoid over-burdening respondents (particularly for unfamiliar and/or complex goods) and over-complicating the models, it is sensible to restrict the number of attributes included in a DCE (Pearce *et al.*, 2002; Johnston *et al.*, 2017). Of the DCE studies reviewed in section 2.3, the mean number of attributes was 4.1 for the outcome uncertainty studies, and 4.7 for the simpler urban forest studies – five attributes was therefore considered the maximum possible for the present study. An attribute representing the price of the good is necessary if WTP values are to be derived, whilst most of the studies reviewed in sub-section 2.3.3 included a specific uncertainty attribute. Inclusion of price and uncertainty attributes in the Southampton DCE meant up to three ES attributes could also be incorporated. Whilst this thesis focuses primarily on the regulating ES of air purification, heat amelioration and stormwater attenuation, the attributes included within a DCE must be those deemed most relevant and important to respondents if the variability in behavioural responses is to be explained (Hensher *et al.*, 2005; Johnston *et al.*, 2017). The worldwide citizen preference literature reviewed in sub-section 2.3.1 revealed aesthetic beauty to be citizens' preferred urban forest ES, followed by heat amelioration and air purification, with stormwater attenuation seemingly of little importance. However, the results of Objective 1 and 2 of the thesis suggested that stormwater attenuation is more important than heat amelioration in the context of UK cities (and specifically Southampton). Air purification, stormwater attenuation and aesthetic beauty were therefore included in the DCE, along with uncertainty and price.

Hensher *et al.* (2005) point out that poorly defined attributes can mean different things to different people, leaving the analyst less able to explain citizens' choices. This is a particular danger for non-market environmental goods or services that are unfamiliar and possibly quite abstract to citizens (Börger and Hattam, 2017), as is often the case with regulating ES. Consequently, rather than describing air purification in terms of tonnes of airborne pollutants removed (as it is in i-Tree Eco studies) it is described here as reductions in the number of pollution-related deaths. The baseline mortality level for particulate matter in Southampton of 115 deaths per year was obtained from Public Health England (2016); with a reduction of approximately 6% from maximum tree planting (taking Southampton's canopy cover from 18.5% to 25%)[47] derived from The Nature Conservancy (2016). Similarly, instead of litres of surface water run-off avoided, stormwater attenuation is described here as reductions in the number of residential properties at risk of surface water flooding. The baseline level of 10,000 properties was extrapolated down from the figures provided for England by the Environment Agency (2014), with a reduction of approximately 4% (again based on increasing Southampton's canopy cover to 25%)

[47] An i-Tree Eco study in Southampton revealed existing canopy cover of 18.5%, and a reported maximum target of 25% (Mutch *et al.*, 2017).

derived from Armson *et al.* (2013). Aesthetic beauty, outcome uncertainty and price were also described so as to be clear and meaningful to respondents – see Table 5.1 on p.136.

To limit hypothetical bias, it was stressed to respondents that paying for tree planting would reduce the amount they have available for their other expenditures, and so they should only choose the alternatives that they can afford. For the same reason, respondents were told that their choices would be shared with the council (and thus help to influence future policy in Southampton), and that, should the proposed tree programme be adopted, compulsory tax-based payments would be required.

5.2.3.2 The experimental design

Experimental design refers to the process of generating specific combinations of attributes and levels that respondents evaluate in choice questions (known as choice tasks). A D-efficient experimental design was used for this DCE, generated using the software package Ngene (ChoiceMetrics, 2018). D-efficient designs are frequently used in DCEs because they minimise standard errors in the estimation of the parameters of the utility function, improving the accuracy and precision of WTP estimates (Rose and Bliemer, 2009).

D-efficient designs are optimised based on a set of 'priors', i.e. estimates of the sign and ideally the magnitude of the parameter coefficients, based on previous similar studies (Ferrini and Scarpa, 2007). When there are no or very few of such studies, Bliemer (2016) recommends that values just above or below zero are chosen for the priors, as the sign will help to avoid dominated pairs of choice alternatives (Johnson *et al.*, 2013). However, Rose and Bliemer (2009) note that the further the priors are from zero, the more efficient the design will be, and furthermore, that efficient designs are fairly robust to misspecification of the priors at the time of constructing the design. Consequently, values in the range -1 to +1 were used for the priors, with signs and magnitudes estimated based on the results of Objective 1 and 2 of the thesis, the literature review supporting Objective 3, and the pre-test stage of the DCE (see sub-section 5.2.3.3). The priors used in the design are set out in Table 5.2.

The number of parameters included in the utility functions, along with the numbers of attributes, levels, and alternatives, determine the minimum number of per-respondent choice tasks necessary for model estimation. The likely sample size will also influence this, as more choices overall will improve the statistical efficiency. In this case, 12 choice tasks were required.

Table 5.2: Priors used in the D-efficient experimental design

Variable name (and type)	Parameter type (and distribution)	Priors used
ASC (categorical)	Fixed (n/a)	0.5
AirQ (continuous)	Random (normal)	0.8 (mean), 0.7 (std devn)
Flood (continuous)	Random (normal)	0.2 (mean), 0.1 (std devn)
ObjCert (continuous)	Random (normal)	0.2 (mean), 0.1 (std devn)
AppLarge (categorical)	Fixed (n/a)[48]	0.5
AppMixed (categorical)	Fixed (n/a)	0.5
Payment (continuous)	Fixed (n/a)[49]	-0.5
AirQ*ObjCert (continuous)[50]	Random (normal)	0.2 (mean), 0.1 (std devn)
Flood*ObjCert (continuous)	Random (normal)	0.2 (mean), 0.1 (std devn)

5.2.3.3 Pre-testing and piloting

Qualitative pre-testing, conducted face-to-face with a small number of respondents (as representative of the target group as possible), is necessary to ensure the comprehension, credibility, and appropriateness of the survey (Johnston *et al.*, 2017). The citizens in this case were recruited via word of mouth, and were generally acquaintances of University colleagues. There were four stages to the pre-testing phase, with the questionnaire undergoing improvements after each one:

a) Completion of survey by, and feedback from, supervisors, friends and family of the researcher (n = 8), during June 2018.
b) Focus group with undergraduate and postgraduate students of the University of Southampton (n = 7), facilitated by the researcher in June 2018. This combined open ended questions to explore participants' perceptions on and use of language around the general subject of the survey, with more specific feedback requested on the format and wording of individual survey questions.
c) Focus group with citizens of Southampton (n = 5), facilitated by the researcher in July 2018. This followed the same format as the student focus group, though participants additionally answered a set of draft choice questions.

[48] Though entering the design as fixed variables (and modelled this way at the pre-test and pilot stages), AppLarge and AppMixed were later modelled as random variables in order to explore the preference heterogeneity associated with these variables (see sub-section 5.3.3).

[49] The parameter representing the marginal value of income ('payment' in this case) is often fixed in DCEs to avoid negative and/or extreme WTP values that may result from use of a random payment parameter, as well as to facilitate model convergence (Hensher and Greene, 2003; Bliemer and Rose, 2013).

[50] Both EUT and direct utility models were included in the experimental design.

d) One-on-one interviews between the researcher and citizens of Southampton (n = 8), conducted during June-July 2018. This followed the same format as the citizen focus group.

After pre-testing and modifying the survey, it was piloted online with a sub-sample of citizens more representative of Southampton's population. This involved mailing postal invitations to 500 citizens selected at random from the city council's electoral open register. A total of 43 respondents completed the online survey over a period of two weeks in July 2018, with 19 for the certain version, and 24 for the uncertain version. This provided an indication of the expected response rate (8.6%).

The quantitative pilot study also enabled the initial testing of the hypotheses by estimating the models described in the following sub-section. All of the models converged successfully, but not all of the coefficients were significant, for example, AirQ was only significant in the uncertain sub-sample. Furthermore, with the exception of the Flood and Payment variables, the magnitude of the parameter coefficients was quite different to that predicted for the experimental design. For the ASC and the objective certainty variable the coefficients were much larger than the respective priors (at 2.11 and 0.59 respectively); for the air quality variable the coefficient (0.23) was much smaller than the prior; and for large trees and the two interaction terms the coefficients were very close to zero. For mixed trees, the coefficient was negative (-0.16) rather than positive.

Despite the differences, the experimental design was not changed following the pilot data modelling results, as using these results as priors did not improve the quality of the design (due to dominated pairs). Thus it was decided best to continue with the same choice design as used in the pre-test and pilot phases. Changes were made to the questionnaire as a result of pre-testing and piloting, however – in particular:

- Removing four questions relating to respondents' exposure to and experience of pollution-related health conditions and surface water flooding in order to reduce the length of the questionnaire, as answers varied very little.
- Explaining the concept of outcome uncertainty in a more concise manner, and simplifying the description of the uncertainty attribute, due to miscomprehension by a minority of citizens from the pre-test. This included changing the way in which the different levels were displayed for the objective certainty attribute, and editing the graphic used for explaining the concept of outcome uncertainty to ensure the two were more similar.
- Changing the attribute levels from 2, 4 or 6 fewer pollution-related deaths to 1, 4 or 7, and from 100, 250 or 400 fewer properties at risk of flooding to 100, 300 or 500 in order to increase the range between levels. The objective certainty levels were changed from

30%, 60% or 90% certain to 40%, 70% or 100% certain in order to aid comparison with the certain sub-sample. The payment levels were also changed, from £1, £2, £4, £6, £8 per month, to £2, £5, £8, £11, £14 per month. This was to increase the range between levels, to ensure the intervals were all the same, and because the pre-test stage suggested that around £10 per month was the upper limit for most people.

- Emphasising that each of the 12 choice tasks were similar (but different) combinations of possible tree programmes, and that each choice is independent of the other choices. This was due to feedback from a minority of citizens from the pre-test who felt as if they were being tricked by being asked the same question more than once, or that they had to remember how they had answered a previous question in order to answer the next.
- Emphasising that responses to the socio-demographic questions are completely anonymous, and adding a 'prefer not to say' box to all questions. This was due to a reluctance amongst some respondents in the pilot study to reveal their household income or ward, as well as GDPR-related concerns of the University ethics committee.
- Adding an open comment box at the end of the questionnaire in order to capture additional thoughts on tree planting in Southampton.
- Adding an optional prize draw in an attempt to increase the response rate.

An example of one of the choice tasks used in the uncertain version of the questionnaire for the main data collection phase is provided in Figure 5.1. The order of the 12 choice tasks was randomised to control for order effects, as initial choices could be biased by learning effects, and later choices by fatigue effects.

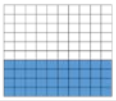
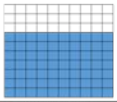
	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	7 fewer pollution-related deaths	4 fewer pollution-related deaths	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	500 fewer properties at risk of flooding	100 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	40% chance of reductions in deaths and flood risk occurring 	70% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Large trees planted 	Small trees planted 	No change 
Payment by your household to support new street tree planting in the city	£96 per year (£8 per month)	£24 per year (£2 per month)	£0
Your choice	☐	☐	☐

Figure 5.1: Example choice task from 'uncertain' version of the questionnaire

5.2.4 Model specification and hypotheses

The utility functions and hypotheses associated with each of the four research questions are set out below.

Research Question 1: To what extent are citizens willing to invest in a PES scheme that focuses on urban forest-based air purification, stormwater attenuation, and aesthetic enhancement?

Tree planting schemes are typically undertaken with either a general reference to a bundle of ES, or no mention of ES provision at all. The purpose of RQ1 therefore, is to ascertain the level of citizen interest in paying for tree planting that is designed specifically to enhance the provision of individual ES.

The utility function for RQ1 is specified as per Model 1 (certain dataset only):

$$U = \alpha + \beta_1 AirQ + \beta_2 Flood + \beta_3 AppLarge + \beta_4 AppMixed + \beta_5 Payment + \mathcal{E} \qquad (7)$$

Null hypothesis H_10: Citizens are not willing to pay for the tree planting programme[51] or any of its components (the air quality benefit, the flood benefit, the aesthetic benefit of large/mixed trees):

- Mean WTP[AirQ] = $\beta_1/-\beta_5 = 0$
- Mean WTP[Flood] = $\beta_2/-\beta_5 = 0$
- Mean WTP[AppLarge/AppMixed] = $\beta_3/-\beta_5 = \beta_4/-\beta_5 = 0$
- Mean WTP[Programme] = $\alpha/-\beta_5 + \beta_1/-\beta_5 + \beta_2/-\beta_5 + \beta_3/-\beta_5 + \beta_4/-\beta_5 = 0$

The alternative hypothesis H_11, i.e. that citizens *are* willing to pay for the programme, or for at least one of the benefits, is confirmed when at least one of the mean WTP values is statistically significantly different from zero.

Research Question 2: To what extent is citizen WTP for air purification, stormwater attenuation and the PES scheme as a whole, affected by the objective uncertainty associated with delivery of these urban ES?

If the provision of ES *is* mentioned in relation to tree planting schemes, it is generally implied that these ES will occur with certainty. The purpose of RQ2 therefore, is to ascertain what might happen to the level of citizen interest in paying for tree planting focused on ES provision if the uncertainty relating to ES outcomes is revealed.

For RQ2, Model 2 is specified with the following utility function (uncertain dataset only):

$$U = \alpha + \beta_1 AirQ + \beta_2 Flood + \beta_3 AppLarge + \beta_4 AppMixed + \beta_5 Payment + \beta_6 ObjCert + \mathcal{E} \qquad (8)$$

This model is a direct utility model. Alternative models (i.e. expected utility and direct-partial expected utility models) were also tested to see which model fit the data best (see **Appendix D**).

Null hypothesis H_20: There is no WTP for improving the objective certainty regarding the delivery of air quality and flood outcomes, and so WTP for the programme[52] overall (and for air purification and flood reduction) is the same for Models 1 and 2:[53]

- Mean WTP[ObjCert] = $\beta_6/-\beta_5 = 0$
- Mean WTP[$Programme_{M1}$] - WTP[$Programme_{M2}$] = 0

[51] WTP for a tree planting programme depends on the attribute levels. All references to 'the programme' in this and later sections are based on a programme with the lowest attribute levels for the three ES, i.e. 1 fewer pollution-related death, 100 fewer properties at risk of flooding, and small trees (of one species) planted.

[52] Except where specified, WTP for 'the programme' is based on the *highest* level for the objective certainty attribute, i.e. 100%. This is in order to aid comparison between the different models, where some respondents received the certain version of the survey, and some the uncertain version.

[53] In this study, the mean WTP values of two empirical distributions are compared using a (one-sided) 'Poe test' of equality of means (Poe *et al.*, 2005).

- Mean WTP[$AirQ_{M1}$] - WTP[$AirQ_{M2}$] = 0
- Mean WTP[$Flood_{M1}$] - WTP[$Flood_{M2}$] = 0

The alternative hypothesis $H_2 1$ is confirmed when WTP for objective certainty, and any of the above mean WTP (difference) estimates, is significantly different from zero.

Research Question 3: Is citizen WTP for air purification and stormwater attenuation, and for improving objective certainty, affected by the subjective uncertainty people associate with delivery of these urban ES?

It is possible that, regardless of whether ES outcomes of tree planting are implied as being certain or objectively revealed to be uncertain, people may base their investment decisions on their own subjective beliefs about ES provision (which may or may not differ from the objective information). The purpose of RQ3 therefore, is to identify whether respondents (in both the control and treatment groups) are influenced by their subjective beliefs relating to the ability of trees to reduce air pollution and surface water flooding when making their tree programme choices.

In RQ3, the two datasets are merged together. As only the uncertain version of the survey contains the uncertainty attribute, an unvarying value of 100% is used as the objective certainty level in the case of all choices made by respondents in the control group (as certainty is implied through the scenario). However, the presence of an extra attribute specifying the differing levels of outcome certainty could increase the randomness of citizen choices in the treatment group compared to those in the control group. In order to merge the two datasets, it is necessary to control for this randomness by including the relative scale parameter (σ_R), estimated as per equation (6) on p.135. This is because the treatment scale parameter (σ_T) can only be estimated relative to the normalised scale parameter for the control group (σ_C).

The utility function for RQ3 is estimated for the merged dataset firstly *without* the inclusion of subjective certainty, as per Model 3a:

$$U = \sigma_R(\alpha + \beta_1 AirQ + \beta_2 Flood + \beta_3 AppLarge + \beta_4 AppMixed + \beta_5 Payment + \beta_6 ObjCert) + \mathcal{E} \quad (9)$$

To ascertain the effect of subjective uncertainty on people's utility for the objectively uncertain ES outcomes, three new variables are required (entered into Model 3b as interaction terms with the AirQ, Flood and ObjCert variables):

a) SubjCertAirQ – a continuous variable (0-10) reflecting respondents' subjective beliefs about the likely effectiveness of tree planting for reducing air pollution.

b) SubjCertFlood – a continuous variable (0-10) reflecting respondents' subjective beliefs about the likely effectiveness of tree planting for reducing surface water flooding.
c) SubjCertES – a continuous variable (0-10) reflecting respondents' subjective beliefs averaged across these two ecosystem services (ES).

The utility function for Model 3b (explicitly accounting for subjective certainty) is therefore:

$$U = \sigma_R(\alpha + \beta_1 AirQ + \beta_2 Flood + \beta_3 AppLarge + \beta_4 AppMixed + \beta_5 Payment + \beta_6 ObjCert + \lambda_1 AirQ*SubjCertAirQ + \lambda_2 Flood*SubjCertFlood + \lambda_3 ObjCert*SubjCertES) + \mathcal{E} \quad (10)$$

Here, λ_1 reflects the impact of people's subjective beliefs regarding air quality benefits on their preferences for the AirQ attribute; λ_2 reflects the impact of people's subjective beliefs regarding flood benefits on their utility for the Flood attribute; and λ_3 reflects the impact of people's subjective beliefs in general on their utility for the ObjCert attribute.

Null hypothesis H_30: Utility for improving air quality, flood, and objective certainty outcomes is unaffected by respondents' subjective uncertainty about the delivery of those outcomes. This is tested by looking at the significance of the lambdas in Model 3b and comparing the WTP values of Models 3a and 3b:

- $AirQ*SubjCertAirQ_{M3b} = \lambda_1 = 0$
- $Flood*SubjCertFlood_{M3b} = \lambda_2 = 0$
- $ObjCert*SubjCertES_{M3b} = \lambda_3 = 0$
- Mean WTP$[AirQ_{M3a}]$ - Mean WTP$([AirQ_{M3b}]+[AirQ*SubjCertAirQ_{M3b}]) = 0$
- Mean WTP$[Flood_{M3a}]$ - Mean WTP$([Flood_{M3b}]+[Flood*SubjCertFlood_{M3b}]) = 0$
- Mean WTP$[ObjCert_{M3a}]$ - Mean WTP$([ObjCert_{M3b}]+[ObjCert*SubjCertES_{M3b}]) = 0$

The alternative hypothesis, H_31, is confirmed when utility for improving these three outcomes *is* affected by respondents' subjective uncertainty, i.e. when any of the above lambdas or mean WTP (difference) estimates is significantly different from zero. In this case, excluding subjective uncertainty as a parameter from the model means that the effect is absorbed in the error term.

Research Question 4: To what extent is citizen WTP for a PES scheme different for respondents experiencing either objective uncertainty over ES outcomes, subjective uncertainty over ES outcomes, or both objective and subjective uncertainty together, compared to respondents who experience no outcome uncertainty?

The literature reviewed in sub-section 2.3.3 suggests that citizen WTP is higher for environmental programmes the more (objectively) certain are the outcomes, whilst psychology and other studies (e.g. Lord *et al.*, 1979; Taber and Lodge, 2006; Sunstein *et al.*, 2017) suggest that subjective beliefs

are prioritised over objective information where these conflict. The purpose of RQ4 is to compare the effects that objective and/or subjective uncertainty can have on WTP for a PES scheme, in order to help potential PES scheme managers decide whether to provide (objective) information on ES outcome uncertainty, and/or whether to obtain information on people's subjective beliefs about ES provision.

RQ3 used continuous variables representing differing levels of objective and subjective uncertainty, and ascertained the effect of the latter through interactions with the various attributes. In contrast, RQ4 looks at the direct effect of the two different types of uncertainty (both relating only to air purification and stormwater attenuation) on WTP for the tree planting programme overall, by segmenting respondents into four (un)certainty situations. To identify this effect, two new variables are required, plus an interaction of the two together:

a) ObjUncertD – a dummy variable that takes the value 1 if the objective certainty of the alternative is 40% or 70%, and 0 otherwise (i.e. when the alternative has 100% or implied objective certainty).
b) DoubterD – a dummy variable that takes the value 1 for respondents with SubjCertES ≤7 (representing the 'doubters'), and 0 otherwise (i.e. for respondents with SubjCertES >7, representing the 'trusters').[54]

For RQ4, the utility function is specified as per Model 4 (for the merged dataset):

$$U = \sigma_R (\alpha + \beta_1 AirQ + \beta_2 Flood + \beta_3 AppLarge + \beta_4 AppMixed + \beta_5 Payment + \gamma_1 ObjUncertD + \gamma_2 DoubterD + \gamma_3 ObjUncertD{*}DoubterD) + \mathcal{E} \quad (11)$$

Estimating this model[55] allows comparisons to be drawn across four possible (un)certainty situations (with mean WTP calculated for each in the normal way):

a) α captures the utility associated with having a tree planting programme rather than the status quo, based on a) small trees being planted; b) outcomes being objectively certain (those stated or implied to be 100% certain); and c) outcomes being subjectively certain (i.e. for respondents who are trusters). This reflects the reference situation 'truster and certain', or 'TC'.

[54] The researcher's decision to represent doubters as those respondents with subjective certainty of ≤7 (averaged across the two regulating ES) was made for the sake of consistency with the objective certainty attribute, whereby the levels 40% and 70% both represent uncertainty in the delivery of air quality and flood outcomes.

[55] Whilst transforming continuous variables into dummy variables, and interacting them with the ASC rather than with the (other) attributes, are simplifications, this approach is similar to that used by Lundhede *et al.* (2015), and was considered an appropriate way to test the overall effect of two different types of outcome uncertainty on choices.

b) γ_1 captures the (dis)utility associated with outcomes being objectively uncertain (those stated to be 40% or 70% certain), as opposed to the reference situation α where outcomes are objectively certain. This reflects the objectively uncertain situation 'truster and uncertain', or 'TU'.

c) γ_2 captures the (dis)utility associated with being a doubter (for whom outcomes are subjectively uncertain), as opposed to the reference situation α where respondents are trusters. This reflects the subjectively uncertain situation 'doubter and certain', or 'DC'.

d) γ_3 captures the additional (dis)utility experienced by doubters presented with objectively uncertain outcomes, compared to trusters presented with objectively uncertain outcomes. The addition of $\gamma_1 + \gamma_2 + \gamma_3$ therefore reflects the combined uncertainty situation 'doubter and uncertain' or 'DU'.

Null hypothesis $H_4 0$: Utility for the programme is unaffected by objective and/or subjective uncertainty, and so WTP does not vary across the four (un)certainty situations.

- $\gamma_1/-\beta_5 = \gamma_2/-\beta_5 = \gamma_3/-\beta_5 = 0$
- Mean WTP[TC] = Mean WTP[TU] = Mean WTP[DC] = Mean WTP[DU]

Alternative hypothesis $H_4 1$: Utility for the programme is negatively affected by objective and/or subjective uncertainty, and so the certainty situation results in higher WTP than the three uncertainty situations.

- $\gamma_1/-\beta_5 < 0$
- $\gamma_2/-\beta_5 < 0$
- $\gamma_1/-\beta_5 + \gamma_2/-\beta_5 + \gamma_3/-\beta_5 < 0$
- Mean WTP[TC] > Mean WTP[TU,DC,DU]

Alternative hypothesis $H_4 2$: Subjective certainty influences utility to a greater extent than objective certainty does, such that trusters always have higher mean WTP for the programme than doubters.

- $\gamma_1/-\beta_5 > \gamma_1/-\beta_5 + \gamma_2/-\beta_5 + \gamma_3/-\beta_5$
- $\gamma_1/-\beta_5 > \gamma_2/-\beta_5$
- Mean WTP[TU] > Mean WTP[DC,DU]

Alternative hypothesis $H_4 3$: Among doubters, the effect of objective uncertainty on WTP for the programme is positive (for example due to enhanced realism or credibility).

- $\gamma_1/-\beta_5 + \gamma_2/-\beta_5 + \gamma_3/-\beta_5 > \gamma_2/-\beta_5$
- Mean WTP[DU] > Mean WTP[DC]

All modelling for this chapter is carried out using the software package 'R version 3.5.1' (The R Foundation, 2018). Additional statistical analysis, i.e. t-tests, chi-squared tests, and linear regression, are performed using the software package 'IBM SPSS Statistics 24' (IBM, 2016).

5.2.5 Data collection

As with the pilot, the main survey was hosted on the University of Southampton's 'iSurvey' website. Postal invitations were sent to 6,500 randomly selected citizens of Southampton in early September 2018, with online responses required by the end of the month; postal reminders were sent out two weeks into the survey period.

Ethical approval for the survey was granted by Ethics and Research Governance Online (ERGO 41035) at the University of Southampton. Participating citizens have been provided with unlinked anonymity (or linked anonymity in the case of those entering the prize draw).

5.3 Results

5.3.1 Respondents' characteristics and attitudes

In total, 415 citizens of Southampton attempted the online survey – a response rate of 6.4%.[56] Of these, 53 (12.8%) failed to complete the choice questions, so are excluded from the choice models – although not from the analysis of citizen attitudes towards ES (see sub-section 5.3.1.1). Of the 362 respondents who completed the choice questions, 271 (74.9%) always chose to pay for tree planting; 65 (18.0%) sometimes chose to pay for tree planting; and the remaining 26 (7.2%) always chose the 'no tree programme'.

Of these 26 respondents, a total of 23 (6.4% of those completing the choice questions)[57] were identified as protesters. The main reasons these protesters gave for not wanting to pay for the tree planting programme were that the council should pay from existing taxes (n = 12), someone else should pay (n = 10), or that they did not trust the council to deliver the programme successfully (n = 10).[58] The protesters made up 7.3% of the control group (the sub-sample of

[56] The literature suggests that response rates to online surveys are likely to be lower than other survey methods (e.g. Manfreda *et al.*, 2008; Shih and Fan, 2009), for example, Marta-Pedroso *et al.* (2007) had a response rate of just 5%. Using postal mail to advertise a web-based survey (i.e. combining two methods) is likely to have reduced the response rate further. Needham *et al.* (2018) obtained a slightly higher response rate of 14.8% using the same approach, though had a higher drop-out rate, at 20.8%.

[57] The protest rate of 6.4% is low compared to most of the studies reviewed in sub-section 2.3.2, where protest rates ranged from 4.9% to 48.6%, with a mean of 17.2%.

[58] Respondents were able to choose more than one reason from the list provided.

respondents who received the 'certain' version of the survey), and 5.3% of the treatment group (the 'uncertain' sub-sample) – these proportions are not significantly different (ν = 192, t = 0.767, P = 0.222). Excluding the protesters from the choice models leaves 339 respondents in the modelled dataset (a total of 4,068 observations). The certain sub-sample therefore contains 105 respondents (1,260 observations), whilst the uncertain sub-sample contains 234 respondents (2,808 observations).

The socio-demographic characteristics of the respondents are reported in Table 5.3 below. The respondents were significantly older (ν = 5, χ^2 = 28.451, P < 0.001) and more educated (ν = 5, χ^2 = 14.175, P = 0.015) than the Southampton population overall. Other differences were not statistically significant. The purpose of the present study is not to estimate aggregate WTP values for Southampton as a whole, but to analyse preference heterogeneity and the effect of objective and subjective uncertainty on WTP – as such, representativeness is less of a concern. Chi-squared tests similarly revealed that the certain and uncertain sub-samples are not significantly different from each other in terms of socio-demographics.

Table 5.3: Socio-demographic characteristics of sub-samples vs. Southampton population

Characteristic	Southampton population	Sample population[a]	Certain sub-sample	Uncertain sub-sample
Age (ONS, 2015):				
18-22	15.5%	3.6%	3.9%	3.5%
23-29	17.1%	9.4%	7.8%	10.1%
30-39	18.2%	12.8%	11.8%	13.2%
40-49	14.4%	19.5%	20.6%	18.9%
50-64	18.4%	31.9%	33.3%	31.3%
65+	16.4%	22.8%	22.5%	22.9%
Gender (ONS, 2015):				
Male	50.8%	56.1%	52.9%	57.5%
Qualification attainment (NOMIS, 2017):				
No qualifications	7.4%	3.2%	5.1%	2.3%
Level 1	9.6%	7.6%	7.1%	7.9%
Level 2	15.0%	13.1%	11.2%	13.9%
Level 3	24.2%	14.6%	11.2%	16.2%
≥Level 4	36.0%	51.6%	55.1%	50.0%
Other	7.8%	9.9%	10.2%	9.7%
Annual household income[b]:				
<£15,000	n/a	10.9%	9.9%	11.3%
£15,000-£24,999	n/a	17.1%	13.6%	18.6%
£25,000-£39,999	n/a	22.5%	21.0%	23.2%
£40,000-£59,999	n/a	22.2%	27.2%	20.1%
£60,000-£79,999	n/a	12.0%	8.6%	13.4%
£80,000-£99,999	n/a	8.0%	13.6%	5.7%
≥£100,000	n/a	7.3%	6.2%	7.7%

[a] Number of respondents = 339 (105 certain and 234 uncertain)

[b] Categorical data for annual household income is not available for Southampton, however, the mean annual *individual* income is £24,367 (ONS, 2017). The mean annual individual income for the sample (based on a sample mean of 1.86 adults with income per household) is £26,076, with a 95% confidence interval of £24,091 - £28,061. As the population mean lies within this confidence interval, the income of the sample vs. Southampton as a whole are not significantly different.

5.3.1.1 Attitudes towards urban forest ecosystem services

With the exception of increasing house prices, all of the listed tree benefits were considered either very or quite important to the majority of respondents (see Figure 5.2). Air purification was the highest ranked benefit, considered (very or quite) important to 96% of respondents. The other ES included in the later choice tasks, aesthetic beauty and flood reduction, were (very or quite) important to 90% and 79% of respondents respectively.

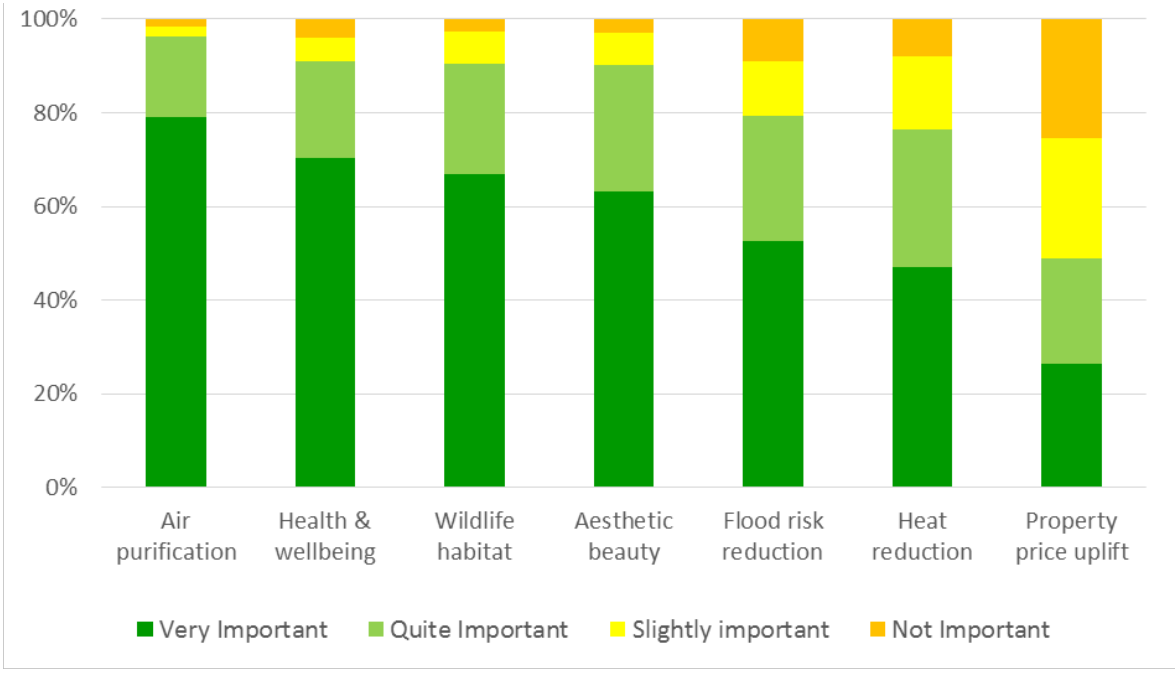


Figure 5.2: Proportion of citizens who consider tree benefits to be important (out of 415)

Specific tree nuisances were generally considered important to only a minority of citizens (see Figure 5.3). Of the listed tree nuisances, damage to pavements caused by tree roots was considered (very or quite) important to the highest proportion of respondents (at 51%). Overall, the mean rating given to the nuisances was significantly lower than that given to the benefits[59] ($v = 5022$, $t = 44.613$, $P < 0.001$).

[59] On a scale of 1-4, where 1 = very important, 2 = quite important, 3 = slightly important, and 4 = not important, the mean nuisance score was 2.91 (most closely reflecting 'slightly important'), and the mean benefit score was 1.68 (most closely reflecting 'quite important').

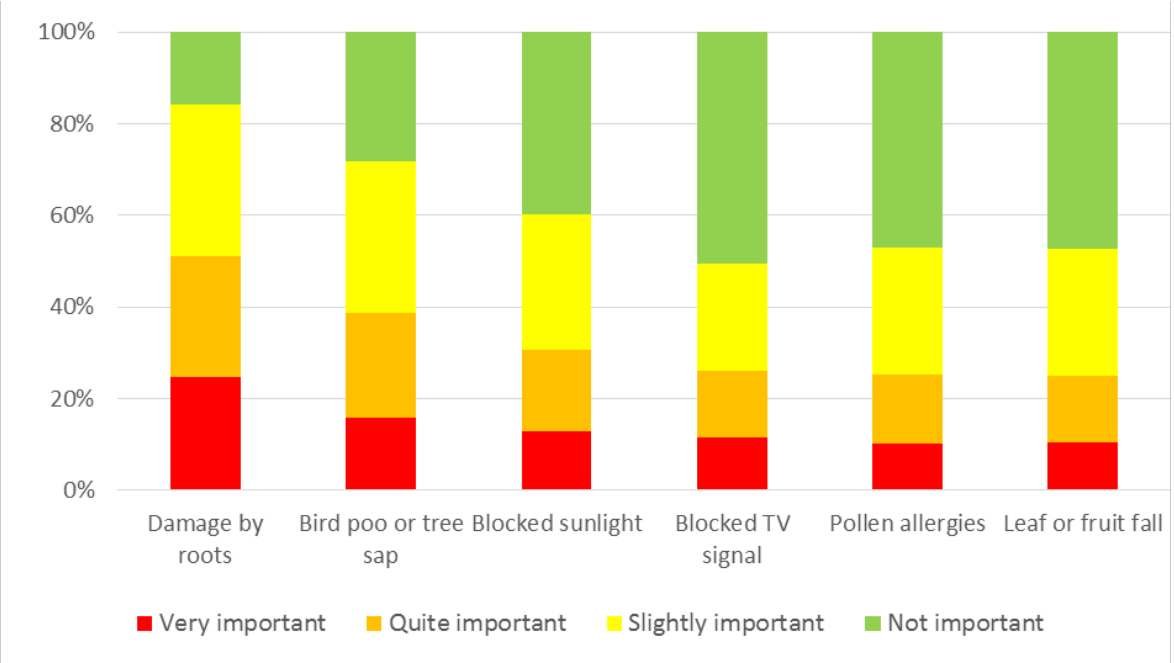


Figure 5.3: Proportion of citizens who consider tree nuisances to be important (out of 415)

Table 5.4 reveals that the majority of respondents were concerned about both air pollution and surface water flooding in Southampton, and (strongly) agreed that the use of both grey and green measures to address these issues would be a good idea.

Table 5.4: Citizens' attitudes towards addressing air pollution and flooding

	Proportion of respondents[a] agreeing with statement (and mean score[b])		
Environmental issue	Concerned about issue	Should prevent issue with grey[c] measures	Should address issue with green[d] measures
Air pollution	88.0% (1.55)	77.8% (1.85)	94.0% (1.30)
Surface water flooding	54.7% (2.18)	94.5% (1.53)	91.1% (1.57)

[a] Number of respondents = 415

[b] These questions used a 5 point Likert scale, where 1 = Strongly agree, 2 = Agree, 3 = Neither agree nor disagree, 4 = Disagree, and 5 = Strongly disagree

[c] Specified 'grey' measures were 'discouraging vehicle use' to prevent air pollution, and 'improving the drainage network' to prevent surface water flooding

[d] Specified 'green' measures were 'planting trees' to both remove air pollution and reduce surface water flooding

However, paired samples t-tests revealed that respondents have significantly different attitudes towards air pollution than they do towards surface water flooding. Firstly, they were significantly *more* concerned about air pollution than about flooding ($v = 400$, $t = -13.557$, $P < 0.001$) – probably because of the recent local and national focus on Southampton's poor air quality record compared to other UK cities (Defra, 2015a). Secondly, respondents were significantly *less* supportive of using grey measures to address air pollution than flooding ($v = 400$, $t = 5.745$, $P < 0.001$). Thirdly, respondents were significantly *more* supportive of using tree planting to address air pollution than to address flooding ($v = 400$, $t = -7.976$, $P < 0.001$).

The main reasons respondents gave for supporting the programme (chosen from a list of eight provided after the choice questions) were to improve air quality (n = 284), to improve aesthetics (n = 226), to reduce flooding (n = 169), and for the feel good factor of improving the city for current and future generations (n = 90). These results suggest that the survey was fit for purpose.

5.3.1.2 Prior and posterior beliefs regarding outcome uncertainty

Each respondent was asked for their prior beliefs (asked *before* the choice tasks) and their posterior beliefs (asked *after* the choice tasks) regarding the certainty with which they felt tree planting would reduce air pollution and surface water flooding in Southampton. Individual subjective certainty scores ranged from 0-10, with an overall mean of 6.8, suggesting a lack of confidence in urban forest ES delivery for some respondents. The mean subjective certainty scores for prior and posterior beliefs regarding air quality and flood benefits are shown in Table 5.5 split by treatment.

Table 5.5: Mean subjective certainty scores of citizens

Benefit (variable name)	Prior or posterior belief	Sample population[a]	Certain sub-sample[a]	Uncertain sub-sample[a]
Reduced air pollution (SubjCertAirQ)	Prior belief	7.4	7.3	7.4
	Posterior belief	7.1	7.1	7.1
Reduced surface water flooding (SubjCertFlood)	Prior belief	6.5	6.6	6.4
	Posterior belief	6.4	6.4	6.3
Average for both ES (SubjCertES)	Prior belief	6.9	6.9	6.9
	Posterior belief	6.7	6.8	6.7

[a] Number of respondents = 339 (105 certain and 234 uncertain)

Table 5.5 shows that respondents' prior beliefs and posterior beliefs were each very similar across the two sub-samples, suggesting that no bias was caused by being in one group or the other (the proportion of trusters and doubters were also very similar across the two sub-samples). Paired samples t-tests revealed that the mean subjective certainty scores for air pollution were significantly higher than those for flooding, both for prior beliefs ($\nu = 333$, $t = 8.561$, $P < 0.001$) and posterior beliefs ($\nu = 330$, $t = 8.723$, $P < 0.001$). Furthermore, the mean posterior belief score was *significantly lower* than the mean prior belief score for air purification ($\nu = 325$, $t = 3.225$, $P = 0.001$), though for flood reduction there was no significant difference ($\nu = 330$, $t = 1.324$, $P = 0.186$). However, a chi-squared test demonstrated no difference in mean score changes across the two sub-samples for air purification ($n = 326$, $\nu = 2$, $\chi^2 = 0.358$, $P = 0.836$),[60] suggesting that the

[60] I.e. the proportion of score changes up, down or staying the same for the two groups matched the expected counts. Similarly, there was no difference between sub-samples for mean score changes regarding flood reduction ($n = 331$, $\nu = 2$, $\chi^2 = 0.235$, $P = 0.889$).

sample-level decline in subjective certainty about air purification was not a result of the treatment. Score changes for individual respondents were therefore explored (see below) in order to identify if respondents altered their beliefs following the receipt of scenario information on ES outcomes (whether implied to be certain, or specified as uncertain) – and if so, to help explain why.

For each of the two regulating ES, individual respondents were classed as either 'trusters' (i.e. those with prior belief scores of $7 < x \leq 10$), 'weak doubters' (those with prior belief scores of $4 < x \leq 7$), or 'strong doubters' (those with prior belief scores of $0 \leq x \leq 4$). These classes were chosen to mimic the objective certainty attribute levels of 100%, 70% and 40%, respectively.[61] Respondents were then categorised based on whether there was a positive, negative, or no discrepancy between their prior beliefs and the objective certainty information they received. Note that a 'discrepancy' between subjective certainty (measured on a continuous scale from 0-10) and objective certainty (which was either implied to be 100%, or stated to vary amongst 40%, 70% and 100%) is impossible to identify precisely. Thus the discrepancy categories are defined as follows:

- Positive discrepancy – occurs where the objective certainty is higher than the respondent's prior belief, i.e. weak doubters receiving the certain version of the survey, and strong doubters receiving either version.
- Negative discrepancy – occurs where the objective certainty is lower than the respondent's prior belief, i.e. trusters receiving the uncertain version of the survey. There is no negative discrepancy for the certain version, where outcomes are implied to occur with 100% certainty, because prior belief scores cannot exceed 10.
- No discrepancy – occurs where objective and subjective uncertainty are equivalent, i.e. trusters receiving the certain version of the survey, and weak doubters receiving the uncertain version of the survey.

Table 5.6 provides this respondent-level analysis, revealing whether individuals (who faced either a positive, negative, or no discrepancy between their prior beliefs and the objective certainty information they received) updated their beliefs, and if so, in which direction.

[61] As a result, the number of respondents in each class varies: for air purification, trusters = 172, weak doubters = 131, strong doubters = 31; for flood reduction, trusters = 117, weak doubters = 167, strong doubters = 55.

Table 5.6: Proportion of citizens facing a discrepancy that updated their beliefs

Discrepancy category	Certain sub-sample [a] % (#)			Uncertain sub-sample [a] % (#)			
	Upwards	No update	Downwards	Upwards	No update	Downwards	Total
Reduced air pollution							
Positive discrepancy	30.6 [b] (15)	44.9 [c] (22)	24.5 [d] (12)	33.3 [b] (6)	61.1 [c] (11)	5.6 [d] (1)	20.6 (67)
Negative discrepancy	n/a	n/a	n/a	12.5 [d] (15)	48.3 [c] (58)	39.2 [b] (47)	36.8 (120)
No discrepancy	8.0 (4)	54.0 (27)	38.0 (19)	31.5 (28)	40.4 (36)	28.1 (25)	42.6 (139)
Total	19.2 (19)	49.5 (49)	31.3 (31)	21.6 (49)	46.3 (105)	32.2 (73)	100.0 (326)
Reduced surface water flooding							
Positive discrepancy	36.8 [b] (25)	35.3 [c] (24)	27.9 [d] (19)	46.3 [b] (19)	41.5 [c] (17)	12.2 [d] (5)	32.9 (109)
Negative discrepancy	n/a	n/a	n/a	7.6 [d] (6)	46.8 [c] (37)	45.6 [b] (36)	23.9 (79)
No discrepancy	8.6 (3)	51.4 (18)	40.0 (14)	33.3 (36)	41.7 (45)	25.0 (27)	43.2 (143)
Total	27.2 (28)	40.8 (42)	32.0 (33)	26.8 (61)	43.4 (99)	29.8 (68)	100.0 (331)

[a] Number of respondents = 339 (105 certain and 234 uncertain)

[b] Respondents who engaged in 'Bayesian updating of beliefs', representing 36.4% of those who faced a discrepancy for air pollution (i.e. n = 68), and 42.6% of those who faced a discrepancy for flooding (i.e. n = 80).

[c] Respondents who ignored the objective uncertainty information, representing 48.7% of those who faced a discrepancy for air pollution (i.e. n = 91), and 41.5% of those who faced a discrepancy for flooding (i.e. n = 78).

[d] Respondents who engaged in 'belief polarisation', representing 15.0% of those who faced a discrepancy for air pollution (i.e. n = 28), and 16.0% of those who faced a discrepancy for flooding (i.e. n = 30).

The mean subjective certainty scores of respondents (shown in Table 5.5 on p.152) suggested that they became significantly less confident (at the 1% level) about the air purification benefits over the course of the survey. However, this pattern is far less clear when looking at belief updating of individual respondents (Table 5.6 above). The difference in the number of respondents updating their beliefs upwards (n = 19) or downwards (n = 31) for air purification is significant only at the 10% level (v = 360, t = -1.401, P = 0.081). Furthermore, the majority of respondents did not update their score (n = 49).

Where belief updating occurred, this was generally in the direction of the objective certainty information the respondent was presented with (see cells marked 'b'). This is known as 'Bayesian belief updating' or 'rational learning', whereby subjective beliefs are modified to account for the new, objective information (Viscusi, 1985; Cameron, 2005). The proportion of Bayesian updaters was higher in the uncertain sub-sample compared to the certain sub-sample, significant at the 10% level (v = 373, t = -1.408, P = 0.080). Given that the treatment group received specific information about uncertainty, this result is not surprising. The proportion of Bayesian updaters

was not significantly different for flood reduction than it was for air purification (v = 373, t = -1.225, P = 0.111).

A relatively large number of respondents stuck to their prior belief scores despite facing a discrepancy with the objective certainty information (see cells marked 'c'). This is likely due to disconfirmation bias, whereby people prioritise their subjective beliefs over conflicting objective information, to the extent that they engage in scenario adjustment or even completely ignore the objective uncertainty information presented to them (Burghart *et al.*, 2007; Huffman *et al.*, 2007). The proportion of objective uncertainty ignorers was significantly higher (at the 10% level) in the uncertain than the certain sub-sample (v = 373, t = -1.508, P = 0.066); and for air purification compared to flood reduction (v = 373, t = 1.396, P = 0.082). The former result may be because the treatment group received specific yet varying information about uncertainty.

A small number of respondents updated their beliefs in the *opposite* direction to the objective certainty information (see cells marked 'd'). Known as 'belief polarisation', this occurs when receipt of objective information that conflicts with a person's prior beliefs causes them to become even more convinced of their initial views (Lord *et al.*, 1979; Corner *et al.*, 2012). The proportion of respondents engaging in belief polarisation was significantly higher in the certain sub-sample than the uncertain one (v = 373, t = 4.053, P < 0.001) – perhaps because they mistrusted the 'supposedly' certain outcomes. There was no difference in belief polarisation for the two ES, however (v = 373, t = -0.263, P = 0.396).

5.3.2 Model estimation results

5.3.2.1 Research question 1

The control group (certain dataset) was used to identify the extent to which citizens would be willing to invest in a PES scheme that focuses on urban forest-based air purification, stormwater attenuation, and aesthetic enhancement.

Model 1 (see equation (7) on p.142) fits the certain sub-sample well ($\rho^2 = 0.43$).[62] The significant, positive value for the ASC (Table 5.7) shows that respondents gain significant utility from the proposal of a tree planting programme (with the baseline of small trees being planted) compared to the status quo alternative of no tree programme. As expected, the results of Model 1 also reveal that respondents gain significant utility from reducing the number of pollution-related

[62] McFadden's adjusted ρ^2 (as used here) is a more appropriate measure of model fit than R^2 for regressions based on maximum likelihood estimation; values of ρ^2 greater than 0.2 represent an 'excellent' fit (McFadden, 1979).

deaths (AirQ), and residential properties at risk of flooding (Flood), and significant disutility from the required annual household contributions to the City Tree Fund (Payment). However, Model 1 indicates that respondents on average have no preference over whether trees planted in Southampton's streets are small or large (AppLarge), and whilst there is some disutility associated with the planting of mixed trees (AppMixed), this is significant only at the 10% level.

Table 5.7: RPL Model 1 estimation and willingness-to-pay (certain dataset)

Attributes	Coefficient (s.e.)	RP std devn (s.e.)[a]	Mean WTP (95% CI)[b]
ASC (tree planting programme, inc. small trees)	4.815*** (0.323)		£128.02*** (£105.54, £154.69)
AirQ (per 1 fewer pollution-related death)	0.287*** (0.100)	0.782*** (0.081)	£7.53*** (£3.24, £11.91)
Flood (per 100 fewer properties at risk of flooding)	0.184*** (0.053)	0.375*** (0.045)	£4.89*** (£2.48, £7.37)
AppLarge (for large rather than small trees)	-0.218 (0.246)	1.981*** (0.260)	n.s. (-£20.08, £8.67)
AppMixed (for mixed rather than small trees)	-0.373* (0.179)	1.170*** (0.217)	-£9.88 (-£20.94, £0.82)
Payment	-0.454*** (0.043)		
Overall tree planting programme[c]			£140.43 (£117.11, £167.44)
No. of observations	1,260		
Log-likelihood	-786.1		
Adjusted ρ^2	0.42		
AIC	1592.2		
BIC	1643.6		

*, **,*** represent statistical significance at 10%, 5% and 1% level, respectively

[a] The random parameters follow a normal distribution[63]

[b] Mean WTP and confidence intervals are calculated per household per year, using Krinsky and Robb (1986) bootstrapping procedures with 2,000 draws

[c] This is based on the lowest levels of the three ES attributes, i.e. the avoidance of one death and 100 properties at risk of flooding, and for the planting of small trees

Table 5.7 also reveals large and significant standard deviations for each of the random parameters – larger than the coefficients themselves – suggesting that whilst some respondents experience positive utility, others experience negative utility. The large standard deviations also contribute to the wide 95% confidence intervals around the WTP values. Possible reasons for the strong

[63] Though some authors (e.g. Hensher *et al.*, 2005) recommend the use of uniform distributions for categorical variables, all of the models fit the data better when AppLarge and AppMixed were normally distributed. For the continuous variables, the normal distribution also led to better model fit than did log-normal distributions, uniform distributions or restricted uniform distributions. The normal distributions were unconstrained, allowing the random parameters to assume negative values.

preference heterogeneity amongst respondents for each of the random parameters is explored in sub-section 5.3.3.

In terms of WTP, respondents were willing to pay an additional £140 per household per year for the basic tree programme, equivalent to an 8% rise in council tax for the average property in Southampton. Though mean WTP is noticeably higher for reducing pollution-related deaths than for reducing flood risk, both have large confidence intervals. Consequently, an equality of means test (following Poe *et al.*, 2005) revealed no significant difference in WTP values for AirQ and Flood (P = 0.151).

To conclude on RQ1, the results of Model 1 show that respondents are willing to invest in the air quality benefit, the flood benefit, and the urban forest PES scheme overall. Null hypothesis H_10 can therefore be rejected (and the alternative hypothesis H_11 accepted).

5.3.2.2 Research question 2

Model 2 (see equation (8) on p.143) was estimated to account for the introduction of outcome uncertainty,[64] using the uncertain dataset (see Table 5.8). Model 2 fits the sub-sample well ($\rho^2 = 0.40$). The attributes have the same sign and significance to those in Model 1, except that the utility for mixed trees over small trees is no longer significantly different from zero. The coefficient for the ObjCert attribute is significant and positive.

The mean WTP values for Model 2 were compared with those of Model 1 using an equality of means test (Poe *et al.*, 2005) to identify the extent to which citizen WTP for air purification and stormwater attenuation is affected by the objective uncertainty associated with delivery of these urban forest ES. WTP for Flood was found to be significantly higher for the treatment group than for the control group (P = 0.008). WTP for AirQ was slightly higher for the treatment group, but not significantly so (P = 0.123). Looking at WTP for the PES scheme as a whole (again based on the lowest levels for AirQ and Flood, and the planting of small trees), this time with objective certainty being explicitly set at 100%, citizens would be willing to pay an average of £223.55 per household per year. This is significantly higher than the WTP of £140.43 by the control group with implied certainty. Even setting ObjCert at 70% results in overall WTP significantly higher than that of Model 1. Only when ObjCert is set at 40% does WTP for the overall tree planting programme become similar across the two models.

[64] Three different versions of the model were estimated, representing expected utility, direct utility, and direct-partial expected utility. The theory behind this is explained in sub-section 5.2.2. The results of the three models, and the reasons for using the direct utility model in the rest of this chapter, are explained in **Appendix D**.

Table 5.8: RPL Model 2 estimation and willingness-to-pay (uncertain dataset)

Attributes	Coefficient (s.e.)	RP std devn (s.e.)[a]	Mean WTP (95% CI)[b]	Poe test p-value for M1 vs M2b[c]
ASC (tree planting programme, inc. small trees)	1.836*** (0.371)		£65.18*** (£40.61, £91.79)	
AirQ (per 1 fewer pollution-related death)	0.297*** (0.054)	0.526*** (0.039)	£10.48*** (£7.83, £12.99)	0.123
Flood (per 100 fewer properties at risk of flooding)	0.263*** (0.037)	0.184*** (0.034)	£9.39*** (£6.78, £12.40)	0.008***
ObjCert (for 100% objective certainty) [65]	0.387*** (0.051)	0.360*** (0.034)	£138.49*** (£96.37, £189.10)	
AppLarge (for large rather than small trees)	0.087 (0.156)	1.785*** (0.165)	n.s. (-£9.43, £15.53)	
AppMixed (for mixed rather than small trees)	-0.086 (0.112)	1.110*** (0.125)	n.s. (-£11.82, £5.88)	0.168
Payment	-0.339*** (0.027)			
Overall tree planting programme[d] (100% ObjCert)			£223.55 (£185.58, £272.19)	0.000***
Overall tree planting programme[d] (70% ObjCert)			£182.00 (£153.66, £218.16)	0.022**
Overall tree planting programme[d] (40% ObjCert)			£140.45 (£119.09, £167.66)	0.498
No. of observations	2,808			
Log-likelihood	-1829.7			
Adjusted ρ^2	0.40			
AIC	3683.4			
BIC	3754.6			

*, **, *** represent statistical significance at 10%, 5% and 1% level, respectively

[a] The random parameters follow a normal distribution

[b] Mean WTP and confidence intervals are calculated per household per year, using Krinsky and Robb (1986) bootstrapping procedures with 2,000 draws

[c] Using Poe *et al.* (2005), the equality of mean WTP values from two empirical distributions is tested (one-sided), using the 2000 draws from the Krinsky and Robb bootstrapping

[d] This is based on the lowest levels of the three ES attributes, i.e. the avoidance of one death and 100 properties at risk of flooding, and for the planting of small trees

To conclude on RQ2, the results of Model 2 show that WTP for ObjCert is significant and positive, whilst WTP for Flood and for the PES scheme overall (at 100% and 70% certainty) are significantly higher compared to Model 1. Thus it appears that WTP for the proposed PES scheme may be *positively* affected by the introduction of information on objective uncertainty. Indeed, respondents were not *put off* the programme by objective uncertainty information, as there was no difference in the proportion of SQ choices between the control and treatment groups – both

[65] The mean WTP for ObjCert is set at 100% objective certainty in order to aid comparison across models – given that Model 1 is based on 100% implied certainty. This does not affect the coefficient, which is measured per 10% increase in objective certainty.

being just under 10% (ν = 4066, t = -0.145, P = 0.443).[66] Null hypothesis H_20 can therefore be rejected (and the alternative hypothesis H_21 accepted). Possible reasons for this – relating to the influence of *subjective* certainty on choices – are explored in more detail through the remaining research questions, and in the discussion.

5.3.2.3 Research question 3

The choices of the treatment and control groups were merged in order to identify whether citizen WTP for air purification and stormwater attenuation benefits, and for improving objective certainty, is affected by people's *subjective* beliefs about the likelihood of delivery of these benefits. Two models were estimated for the merged datasets, the first *without* subjective uncertainty (Model 3a; see equation (9) on p.144), and the second *with* subjective uncertainty (Model 3b; see equation (10) on p.145). Note that Model 3b uses *posterior* beliefs for the SubjCert variables, as these fit the data significantly better than prior beliefs.[67]

The parameter estimates for Model 3a (see Table 5.9) are as expected given the results of Models 1 and 2 (i.e. utility is significant and positive for the ASC, AirQ, Flood, and ObjCert; significant and negative for Payment; and insignificant for AppLarge and AppMixed). In terms of the treatment scale parameter, a value less than one (in this case 0.818) suggests that respondents in the treatment group have more random choices than those in the control group. A t-test confirms that the treatment scale parameter is significantly different from one (ν = 233, t = -2.380, P = 0.018).

Comparing Model 3a with Model 3b, the AIC and the log-likelihood ratio test (P < 0.001) both indicate that introducing subjective uncertainty significantly improves model performance. However, the BIC (which penalises models with more variables) and the adjusted ρ^2 both suggest no significant change. Despite this, there are notable differences between the two models in terms of the parameter estimates for AirQ, Flood and ObjCert.

[66] In contrast, Glenk and Colombo (2011) had significantly more SQ choices in their treatment group (at 19% compared to 13% for their control group).

[67] This was tested by comparing the nested models 'prior' with 'prior+posterior', and 'posterior' with 'prior+posterior', The fit of the composite 'prior+posterior' model was significantly better than the 'prior' model (ν = 6, χ^2 = 24.104, P < 0.001). In contrast, the fit of the composite model was *not* better than the 'posterior' model (the latter having the lower log-likelihood value of the two).

Table 5.9: RPL Model 3a and 3b estimation (merged datasets; effect of SubjCert)

Attributes	Model 3a		Model 3b (with SubjCert)	
	Coefficient (s.e.)	RP std devn (s.e.)[a]	Coefficient (s.e.)	RP std devn (s.e.)[a]
ASC (tree planting programme, inc. small trees)	2.738*** (0.443)		2.877*** (0.460)	
AirQ (per 1 fewer pollution-related death)	0.355*** (0.061)	0.626*** (0.058)	-0.008 (0.133)	0.427*** (0.063)
AirQ*SubjCertAirQ[b] (per 1 fewer pollution-related death)			0.371** (0.133)	-0.465*** (0.065)
Flood (per 100 fewer properties at risk of flooding)	0.271*** (0.035)	0.206*** (0.036)	0.121 (0.072)	-0.134* (0.070)
Flood*SubjCertFlood[b] (per 100 fewer properties at risk of flooding)			0.151** (0.070)	-0.168*** (0.058)
ObjCert (per 10% increase in objective certainty)	0.426*** (0.058)	0.407*** (0.045)	-0.062 (0.110)	0.357*** (0.062)
ObjCert*SubjCertES[b] (per 10% increase in objective certainty)			0.493*** (0.117)	-0.251*** (0.057)
AppLarge (for large rather than small trees)	0.052 (0.149)	2.073*** (0.209)	0.034 (0.152)	2.168*** (0.222)
AppMixed (for mixed rather than small trees)	-0.187 (0.110)	1.262*** (0.153)	-0.185 (0.111)	1.294*** (0.155)
Payment	-0.430*** (0.040)		-0.431*** (0.040)	
Treatment scale parameter	0.818*** (0.076)		0.815*** (0.078)	
No. of observations	4,068		4,068	
Log-likelihood	-2581.6		-2557.5	
Adjusted ρ^2	0.42		0.42	
AIC	5189.1		5153.0	
BIC	5271.2		5272.9	

*, **, *** represent statistical significance at 10%, 5% and 1% level, respectively

[a] The random parameters follow a normal distribution

[b] As stated in sub-section 5.2.4, SubjCertAirQ, SubjCertFlood and SubjCertES are all continuous variables coded 0-10, and vary by respondent

By introducing SubjCertAirQ as an interaction with AirQ in Model 3b, AirQ alone becomes insignificant, whilst the interaction term is significant. The same result is found for Flood and ObjCert. This suggests that respondents factor their subjective beliefs about ES delivery into their choices. Furthermore, the more confidence respondents have in trees' ability to enhance air quality and reduce flood risk, the more utility they gain from increasing the level of the AirQ attribute, the Flood attribute, and the objective certainty surrounding delivery of the two regulating ES.

WTP results for Models 3a and 3b can be seen in Table 5.10. WTP values for Model 3a are comparable to those of Models 1 and 2. When people's subjective beliefs are explicitly

incorporated (i.e. Model 3b), the mean value placed on reducing the number of pollution-related deaths becomes higher, but not significantly so due to the increased variability. Similarly, the mean WTP values for increasing the objective certainty of the benefits of the tree planting programme, and WTP for the overall tree planting programme are not significantly different across the two models. Controlling for heterogeneity in subjective beliefs regarding ES outcome uncertainty therefore does not change mean WTP estimates for the AirQ or ObjCert attributes, or for the programme as a whole.

Table 5.10: RPL Model 3a and 3b willingness-to-pay (merged datasets; effect of SubjCert)

Attributes	Model 3a Mean WTP (95% CI)[a]	Model 3b (+SubjCert) Mean WTP (95% CI)[a]	Poe test p-value[b] for M3a vs M3b[c]
ASC (tree programme, inc. small trees)	£76.65*** (£53.89, £98.67)	£80.23*** (£56.86, £103.28)	0.414
AirQ (per 1 fewer pollution-related death)	£9.90*** (£7.54, £12.20)	n.s. (-£8.70, £8.27)	
AirQ*SubjCertAirQ (per 1 fewer pollution-related death, with subjective certainty of 7.1)		£10.28** (£1.79, £18.50)	0.467
Flood (per 100 fewer properties at risk of flooding)	£7.61*** (£5.99, £9.43)	n.s. (-£0.80, £7.78)	
Flood*SubjCertFlood (per 100 fewer properties at risk of flooding, with subjective certainty of 6.4)		£4.21** (£0.12, £8.34)	0.039**
ObjCert (for 100% objective certainty)	£119.93*** (£89.82, £153.98)	n.s. (-£7.98, £5.28)	
ObjCert*SubjCertES (for 100% objective certainty, with subjective certainty of 6.7)		£137.42*** (£65.86, £210.23)	0.333
AppLarge (large trees)	n.s. (-£7.65, £11.81)	n.s. (-£9.11, £10.50)	
AppMixed (mixed trees)	n.s. (-£11.95, £1.91)	n.s. (-£11.78, £1.49)	
Overall tree planting programme[d]	£214.10 (£184.28, £249.99)	£232.14 (£153.92, £310.65)	0.342

*, **, *** represent statistical significance at 10%, 5% and 1% level, respectively

[a] WTP is calculated per household per year, using Krinsky and Robb (1986) bootstrapping procedures with 2,000 draws

[b] Using Poe *et al.* (2005), equality of mean WTP values from two empirical distributions is tested (one-sided), using the 2000 draws from the Krinsky and Robb bootstrapping

[c] WTP for AirQ in Model 3a is compared with WTP for AirQ*SubjCertAirQ in Model 3b. This is because the coefficient for AirQ in Model 3b was insignificant, and thus WTP is zero. Similarly, WTP for Flood and ObjCert in Model 3a are compared with WTP for Flood*SubjCertFlood and ObjCert*SubjCertES respectively in Model 3b.

[d] This is based on the lowest levels of the three ES attributes, i.e. the avoidance of one death and 100 properties at risk of flooding, and for the planting of small trees

In contrast, mean WTP for reducing the number of properties at risk of flooding is *significantly lower* when heterogeneity in subjective beliefs is controlled for. This suggests that people's subjective uncertainty surrounding trees' ability to reduce flood risk not only influences their

choices, but also reduces their WTP for tree planting aimed specifically at reducing residential flood risk by almost half. The different way subjective certainty affected WTP for Flood compared to WTP for AirQ is likely to arise from the fact that subjective certainty scores relating to stormwater attenuation were significantly lower than those for air purification.

To conclude on RQ3, the results of Model 3b show that utility for improved air quality, flood and objective certainty outcomes *is* affected by respondents' perceptions regarding the likelihood of delivery of air quality and flood benefits. However, null hypothesis H_30 can only be rejected in part (and the alternative hypothesis H_31 accepted in part), because the only significant difference in WTP across Models 3a and 3b is for the Flood outcome. The effect of subjective certainty on WTP for the PES scheme overall is explored in more detail through the following research question.

5.3.2.4 Research question 4

The merged dataset was used to identify the extent to which WTP for a PES scheme differs for respondents who experience one of four different (un)certainty situations – namely, objective uncertainty over ES outcomes (TU), subjective uncertainty over ES outcomes (DC), both objective and subjective uncertainty together (DU), or no outcome uncertainty (TC).[68] Using equation (11) on p.146, the model was estimated using prior beliefs,[69] as it is important to know how people who a priori doubt ES delivery respond to outcomes presented as certain or uncertain, and how this affects their WTP for tree planting.

The parameter estimates for Model 4 (see Table 5.11) are as expected given the results of Model 3a (i.e. utility is significant and positive for the ASC, AirQ, and Flood; significant and negative for Payment; and insignificant for AppLarge and AppMixed). The coefficients for the two new uncertainty dummies in Model 4 (ObjUncertD and DoubterD) suggest that utility is lower for respondents being exposed to objective uncertainty and for those experiencing subjective uncertainty compared to respondents who experience no uncertainty, though the effect of DoubterD is significant only at the 10% level. The interaction term is not significant, suggesting that the level of disutility associated with objective uncertainty is no higher or lower for a priori doubters than it is for a priori trusters.

[68] Note that there are a different number of respondents in each of these groups, as follows: TC = 45; TU = 106; DC = 56; DU = 127.

[69] The model was re-estimated using *posterior* instead of prior beliefs to see how WTP differs between certain and uncertain outcomes for those who trust or doubt ES provision *a posteriori*. The estimations and WTP values for the resulting Model 4b are similar to those for Model 4, and can be found in **Appendix D**.

Table 5.11: RPL Model 4 estimation and willingness-to-pay (experience of objective vs. subjective uncertainty)

Attributes	Coefficient (s.e.)	RP std devn (s.e.)[a]	Mean WTP (95% CI)[b]
ASC (tree planting programme, inc. small trees)	5.441*** (0.376)		£164.00*** (£137.45, £195.22)
AirQ (per 1 fewer pollution-related death)	0.202*** (0.052)	0.669*** (0.052)	£6.08*** (£3.60, £8.43)
Flood (per 100 fewer properties at risk of flooding)	0.077*** (0.028)	0.321*** (0.032)	£2.30*** (£0.84, £3.76)
AppLarge (for large rather than small trees)	-0.003 (0.142)	2.077*** (0.182)	n.s. (-£9.82, £9.19)
AppMixed (for mixed rather than small trees)	-0.164 (0.106)	1.331*** (0.139)	n.s. (-£11.77, £1.76)
ObjUncertD (respondents for whom choices reflect outcomes with 40% or 70% objective certainty)	-0.411** (0.204)		-£12.29** (-£24.92, -£0.01)
DoubterD (respondents for whom the averaged subjective certainty score is ≤7)	-0.825* (0.280)		-£24.75* (-£52.71, £1.24)
ObjUncertD*DoubterD (additional effect of objective uncertainty for doubters)	-0.038 (0.258)		n.s. (-£17.43, £14.16)
Payment	-0.399*** (0.033)		
Treatment scale parameter	0.867*** (0.065)		
Overall programme[c] for truster with objectively certain outcomes (TC) (for whom uncertainty dummies = 0)			£172.38 (£146.67, £202.90)
Overall programme[c] for truster with objectively uncertain outcomes (TU) (for whom ObjUncertD = 1)			£160.09 (£138.40, £186.12)
Overall programme[c] for doubter with objectively certain outcomes (DC) (for whom DoubterD = 1)			£147.62 (£127.04, £171.98)
Overall programme[c] for doubter with objectively uncertain outcomes (DU) (for whom uncertainty dummies = 1)			£135.33 (£113.72, £160.35)
No. of observations	4,068		
Log-likelihood	-2724.9		
Adjusted ρ^2	0.39		
AIC	5477.8		
BIC	5566.2		

*, **,*** represent statistical significance at 10%, 5% and 1% level, respectively

[a] The random parameters follow a normal distribution

[b] Mean WTP and confidence intervals are calculated per household per year, using Krinsky and Robb (1986) bootstrapping procedures with 2,000 draws

[c] The overall programme is based on the lowest levels of the three ES attributes, i.e. the avoidance of one death and 100 properties at risk of flooding, and for the planting of small trees

Table 5.11 shows that for respondents experiencing subjective uncertainty regarding flood and air quality outcomes (DoubterD), the negative impact on mean WTP (compared to the reference situation) is twice as large as the negative impact on mean WTP for those experiencing objective

uncertainty regarding flood and air quality outcomes (ObjUncertD). Indeed, when mean WTP for the overall programme is considered for the four groups of respondents, mean WTP for trusters (represented by TC and TU) is higher than mean WTP of doubters (DC and DU) regardless of the objective certainty information received. In contrast, WTP of those receiving objectively certain information is not necessarily higher than those receiving objectively uncertain information. These findings are supported by the proportion of respondents choosing the SQ. Whilst there was no difference in SQ choices between treatments for either trusters or doubters, there were significantly more SQ choices amongst doubters in both the control and treatment groups. This suggests subjective certainty affects whether people are willing to pay at all, but objective certainty does not.

Equality of means tests (Poe *et al.*, 2005) were used to test whether the differences in mean WTP between each of the four respondent groups were significant or not. WTP for the two subjectively uncertain situations were both found to be significantly lower than WTP for the certain (reference) situation, i.e. TC vs. DC (P = 0.085), and TC vs. DU (P = 0.022); whilst WTP under objectively uncertain outcomes was also significantly lower for doubters than for trusters, i.e. TU vs. DU (P = 0.073). However, no significant difference in WTP was found amongst trusters shown objectively certain (TC) vs. uncertain outcomes (TU) (P = 0.249); between trusters shown objectively uncertain outcomes (TU) and doubters shown objectively certain outcomes (DC) (P = 0.226); or amongst doubters shown objectively certain (DC) vs. uncertain outcomes (DU) (P = 0.232).

To conclude on RQ4, the results of Model 4 show that the WTP for the four different respondent groups can be ranked as follows: TC ≥ TU ≥ DC ≥ DU. Though this is slightly different to the hypothesised ranking of TC > TU > DU > DC, overall, null hypothesis $H_4 0$ can be rejected, as WTP for the tree planting programme *is* affected by the presence of objective, and especially subjective, uncertainty. However, alternative hypothesis $H_4 1$ (TC > TU/DU/DC) and alternative hypothesis $H_4 2$ (TU > DU/DC) can only be accepted in part, as WTP for TU was not (significantly) lower than that for TC, nor (significantly) higher than that for DC. Finally, alternative hypothesis $H_4 3$ (DU > DC) must be rejected: there is no evidence to suggest that doubters prefer the realism/credibility of objectively uncertain outcomes over certain ones.

5.3.3 Conditional distributions and posterior analysis

Estimation of the RPL models in sub-section 5.3.2 revealed large and significant standard deviations for each of the random parameters – larger than the coefficients themselves. This suggests that some respondents experience positive utility, and others experience negative utility

related to changes in each of the attributes. Indeed, based on Model 3a (which used the merged dataset), the number/proportion of respondents with negative WTP was as follows:

- Air purification = 125 respondents (36.9%);
- Flood reduction = 2 respondents (0.6%);
- Objective certainty = 54 respondents (15.9%);
- Large trees = 165 respondents (48.7%); and
- Mixed trees = 198 respondents (58.4%).

Based on records of the choices made by each individual in the choice tasks, conditional distributions were estimated for each coefficient. As expected, the means of the individual conditional means are very close to the corresponding estimated unconditional population means (i.e. the coefficients in Table 5.9). Furthermore, the standard deviations of the conditional means (the 'between' variation) make up a fairly large proportion of the estimated standard deviations shown in Table 5.9 (the latter include both the 'within' variation around the individual conditional means, and the 'between' variation). The heterogeneity in attribute preferences can thus be (partly) explained by differing attitudes and socio-demographic characteristics of individual respondents.

Posterior analysis was therefore undertaken on Model 3a to help explain this strong preference heterogeneity. First, attitudinal and socio-demographic variables which were significantly correlated with a particular attribute (at the 10%, 5% or 1% level), but not significantly correlated with each other (at the 1% level) were identified. These variables were then included in a linear regression model for each attribute. As shown in Table 5.12, some – but not all – of these attitudinal and socio-demographic characteristics were found to be significant predictors of utility for respondents overall.

Many of these results make logical sense, and so support the validity of the model. For example, in terms of attitudes, the importance respondents placed on the air quality and flood reduction benefits of trees strongly influenced their WTP for reducing pollution-related deaths and reducing properties at risk of flooding, respectively. Similarly, the importance respondents placed on the aesthetic and house price benefits of trees – and to a lesser extent on the nuisances relating to blocked sunlight and pollen allergies – strongly influenced their WTP for planting large or mixed trees instead of small ones. In terms of socio-demographic characteristics, it makes logical sense that wealthier individuals are willing to pay more for air purification; and that members of environmental organisations are willing to pay more for air purification, and for having either large or mixed species of trees instead of small ones. Meanwhile, the fact that older respondents

are willing to pay more for flood risk reduction, but less for large trees, could be due to a greater adversity to risk. These results are discussed further in sub-section 5.4.2.

Table 5.12: Determinants of willingness-to-pay for the random parameters of Model 3a

Attribute	Variable (values)	Regression coefficient (s.e.)
Air purification	Reason for WTP: air quality important (1 = yes, 0 otherwise)	0.277** (0.108)
	Posterior belief score for air quality benefit (0 – 10)	0.050*** (0.017)
	Gender (1 = male, 0 otherwise)	0.240*** (0.067)
	Member of environmental organisation (1 = yes, 0 otherwise)	0.290*** (0.087)
	Household income (£7.5k, £20k, £32.5k, £50k, £70k, £90k, £110k)	0.000*** (0.000)
Flood reduction	Benefit: flood reduction (1 = very important, 0 otherwise)	0.023* (0.012)
	Age (20, 26, 34.5, 44.5, 57, 73 years)	0.001* (0.000)
Objective certainty	Reason for WTP: appreciate honesty about uncertainty (1 = yes, 0 otherwise)	0.111** (0.048)
	Posterior belief score for air quality benefit (0 – 10)	0.034*** (0.010)
	Gender (1 = male, 0 otherwise)	-0.042 (0.044)
	Education level (1 = level 4+, 0 otherwise)	0.037 (0.043)
Large trees	Nuisance: blocking light (1 = very important, 0 otherwise)	-0.481 (0.322)
	Reason for WTP: aesthetics important (1 = yes, 0 otherwise)	0.487** (0.216)
	Age (20, 26, 34.5, 44.5, 57, 73 years)	-0.013** (0.006)
	Member of environmental organisation (1 = yes, 0 otherwise)	0.515* (0.265)
Mixed trees	Nuisance: pollen allergies (1 = very important, 0 otherwise)	-0.276 (0.176)
	Benefit: house price increase (1 = very important, 0 otherwise)	0.236** (0.113)
	Member of environmental organisation (1 = yes, 0 otherwise)	0.479*** (0.138)

*, **, *** represent statistical significance at 10%, 5% and 1% level, respectively

The posterior analysis results around uncertainty also make logical sense, as people's WTP for both air purification and the level of objective certainty were strongly influenced by their *subjective* certainty scores for air purification.[70] As subjective certainty scores were obtained from respondents directly, it was possible to identify correlation with other attitudinal and socio-demographic factors without the use of posterior analysis. Unsurprisingly, prior belief scores (averaged for the two ES) were significantly higher for respondents who consider tree benefits to be very important; who strongly agree with the use of nature-based solutions to flooding and pollution issues; and who are members of environmental organisations. Furthermore, prior belief scores were significantly *lower* for respondents who consider tree nuisances to be very important;

[70] Recall that Model 3a – which did *not* incorporate subjective certainty variables – is used for the posterior analysis.

for men; and for those from wealthier households. These results are discussed further in sub-section 5.4.3.

5.4 Discussion

5.4.1 Citizen preferences for urban forest ecosystem services and disservices

At the start of the survey, respondents were asked to indicate how important seven different tree benefits are to them, which enabled these to be placed in order of preference (see Figure 5.2 on p.150). Compared to the list in sub-section 2.3.1 (obtained from the worldwide literature), there are several differences. Most notably, air purification was considered to be the most important ES to citizens in Southampton. Only three of the other 22 studies on citizen preferences found air purification ranked above aesthetic beauty (Derkzen *et al.*, 2017; Tran *et al.*, 2017; Graça *et al.*, 2018), of which two were conducted in cities known for their poor air quality – Rotterdam (The Netherlands), and Atlanta, Georgia (United States) (World Health Organization, 2016). This ordering is likely caused by the overlapping consultation on Southampton City Council's proposed 'Clean Air Zone', which took place during 21st June to 13th September 2018 (Southampton City Council, 2018). This was preceded by years of media attention since the UK Government named Southampton as one of five UK cities requiring designation of a Clean Air Zone due to its continued failure to comply with EU law regarding NO_2 pollution (Defra, 2015a; Franklin, 2016; Rimell, 2018).

Citizens in Southampton also rated stormwater attenuation *above* heat amelioration; a finding shared by just two of the other 22 citizen preference studies (Duke *et al.*, 2016; Derkzen *et al.*, 2017). This may be because Rotterdam (The Netherlands) and Delaware (USA) are both coastal areas at risk of flooding from storm surges. In the case of the present study, this finding is likely to be due to a perception that heat amelioration is less useful in Britain's cool climate, as suggested by respondents to Objectives 1 and 2 of this thesis. Finally, citizens in Southampton rated the health and wellbeing benefits of street trees particularly highly compared to most of the other reviewed studies. Only four studies mentioned this benefit at all, e.g. Madureira *et al.* (2015), despite the increasing scientific evidence of the physical and mental health benefits of urban trees (e.g. O'Brien *et al.*, 2010; Ulmer *et al.*, 2016; Donovan, 2017).

Finally, ecosystem disservices may also influence the utility people derive from urban trees. The Southampton survey focused only on the more commonly occurring disservices that Britain's tree officers receive complaints about (as revealed through Objective 1). Sub-section 5.3.1.1 revealed that tree nuisances were considered significantly less important to Southampton's citizens than

tree benefits, a finding mirrored by all 13 of the other 22 citizen preference studies that discussed disservices. This is useful information, because whilst citizens frequently contact their councils to complain about tree-related problems they wish to see addressed, they do not tend to make positive comments about publicly owned trees (unless the trees come under threat, e.g. from development). Tree roots causing damage to pavements and other infrastructure appears to be the greatest tree nuisance amongst citizens throughout the temperate/developed world – including in Southampton. The blocking of light/sun was also considered problematic in many of the other 13 studies. Bird or aphid excrement falling onto parked cars was the second most important tree nuisance in Southampton, but it ranked only 14th out of the 17 disservices mentioned in the other studies. Conversely, leaves or fruit falling onto pavements, parked cars or into gardens was considered of lower importance in the present study than those conducted elsewhere.

To summarise, regulating and cultural services were both considered important to the majority of respondents in Southampton, with tree benefits rated as significantly more important than tree nuisances. This suggests that (at least some) citizens are likely to be supportive of policy aimed at enhancing the urban forest.

5.4.2 Citizen willingness-to-pay for an urban forest payments for ecosystem services scheme

The majority of respondents to the survey were in favour of paying for street tree planting in Southampton – of the 362 respondents who completed the choice questions, just 7.2% did not support the proposed scheme. The main reasons respondents gave for supporting the programme were to improve air quality, to improve aesthetics, and to reduce flooding, respectively.[71] Mean WTP for the overall tree planting programme per household per year varies depending on the levels of the attributes. Based on a conservative scenario[72] with one less pollution-related death, 100 fewer properties at risk of flooding, and small trees planted (i.e. the lowest levels for the AirQ, Flood and Appearance attributes, respectively), mean WTP in Model 1 was £140.43. A new City Tree Fund of this value would be equivalent to a council tax increase of approximately 8% for

[71] **Appendix D** summarises the written comments (both positive and negative) that a minority of citizens (n = 69) chose to make about the proposed tree planting programme at the end of the survey.

[72] Whilst conservative in terms of the attribute levels, the number of additional, average-sized trees (at least 20cm diameter at breast height) required to achieve such benefits would still be substantial – in the region of 14,000 trees for one less pollution-related death, or 23,500 trees for 100 fewer properties at risk of flooding. This would bring Southampton's tree canopy cover up from 18.5% (as reported in Mutch *et al.*, 2017) to around 20%. By contrast, the highest attribute levels would require planting over 100,000 additional, average-sized trees, bringing tree canopy cover to around 26%. Whilst the Council is aiming for long term tree canopy cover in the region of 25% (Mutch *et al.*, 2017), increasing the number of trees in the city by a third is likely to be unrealistic.

the average property in Southampton. This amount is not unreasonable, suggesting that hypothetical bias (which can cause inflated WTP values) was not an issue in this study. Model 1 represents the typical valuation scenario for environmental programmes, i.e. where uncertainty over outcomes is ignored. Consequently, the results of this model are most useful for comparing with those of other stated preference studies on urban forests.

The mean WTP values for the different urban forest programmes valued in the 20 papers reviewed in sub-section 2.3.2 ranged from £7 to £341 per respondent/household per year (in GPB in 2018 prices). The WTP figure from Model 1 is therefore within the range reported in the other papers, with 17 reporting lower figures, and two reporting higher figures. However, the WTP for urban forest programmes depends on the specific urban forest component being valued, the action or change being proposed, and the associated provision of ES (Barton, 2015; Davies *et al.*, 2017a). For example, comparing these 20 studies, WTP for street trees was found to be higher than that for urban parks or woodlands, though WTP for creating new urban forest components was similar to that for protecting or improving existing ones. Only two of these 20 studies – Morawetz and Koemle (2017), and Soto *et al.* (2018) – sought to place a monetary value on individual ES (as opposed to urban forest enhancements more generally). Neither of these studies valued air purification, stormwater attenuation or aesthetic beauty, making the present study the first to do so.

Model 1 showed that respondents had significant, positive WTP for the air purification and stormwater attenuation benefits of trees. Though mean WTP for air purification was higher than mean WTP for stormwater attenuation, the large confidence intervals around these values meant that the difference between the two was not significantly different. The use of a categorical variable to represent the aesthetic benefits of trees means that it is not possible to assign a monetary value to this ES that would allow comparison with the two regulating ES.[73] Nevertheless, Model 1 showed that overall, respondents had no significant preference for the planting of large street trees (or mixed species) over small trees – in contrast to the findings of Mell *et al.* (2013).

Posterior analysis revealed WTP for reducing the number of pollution-related deaths was partly driven by respondents' subjective beliefs regarding air purification. Though no other stated preference studies have specifically valued the air purification benefits of trees, Ng *et al.* (2015) found that citizen perceptions regarding the ability of trees to improve air quality significantly

[73] This is because WTP for the baseline level of the Appearance attribute (in this case, small trees) is hidden within the ASC of paying for tree planting as opposed to not paying for tree planting.

increased their WTP for street tree planting in Hong Kong. Income and gender were also significant determinants of WTP for AirQ – income is an indicator of theoretical validity in stated preference studies – with wealthier respondents and males expected to be able and willing to pay higher amounts.

There were two significant attitudinal or socio-demographic predictors of utility for reducing the number of properties at risk of flooding (at the 10% level): the importance of the stormwater attenuation benefit of trees to people, and their age. Whilst there are no other stated preference studies that specifically value the stormwater attenuation benefits of trees, other studies valuing flood risk reduction have found some socio-demographic and attitudinal variables to positively influence WTP. These include levels of income and education, as well as the perception that climate change/flood risk is real and/or worsening (e.g. Birol *et al.*, 2009; Botzen *et al.*, 2009; Brouwer and Schaafsma, 2013; Veronesi *et al.*, 2014).

Despite the absence of a sample-wide preference for small, large or mixed trees in the present study, the standard deviations in each of the tables in sub-section 5.3.2 are large, and the confidence intervals around mean WTP values are wide, suggesting strong preference heterogeneity amongst individuals. Posterior analysis revealed that the size and species-mix of street trees is about more than just aesthetics to people. For example, it seems that larger trees are associated with nuisances that the planting of smaller trees can avoid (e.g. excessive shading). There may also be greater awareness amongst the environmentally-minded about the biodiversity and tree resilience benefits of planting a range of different species (Morgenroth *et al.*, 2016), and about the ability of larger trees to provide more ES (Davies *et al.*, 2017a). In terms of socio-demographics, the present study supports the findings of Conway and Yip (2016) that older people are willing to pay more for small-stature street trees than large ones, with the opposite true for younger people.

To summarise, there was strong support amongst respondents for paying for additional street tree planting through the proposed City Tree Fund (effectively a ring-fenced increase to council tax). Furthermore, respondents were willing to pay a small but significant amount extra to secure air purification and flood reduction benefits – particularly people who appreciate and are optimistic about nature-based solutions. This suggests there is likely to be (at least some) support for an urban forest PES scheme in Southampton (and other, similar cities), which could be enhanced by awareness-raising about the benefits of trees.

5.4.3 Effect of uncertainty surrounding ecosystem service delivery on citizen willingness-to-pay

The treatment scale parameter estimated in Model 3a revealed that respondents in the 'uncertain' treatment group have significantly more random choices than those in the 'certain' control group. This can perhaps be expected given the complexity of facing uncertainty, however, the more random choices in the treatment group could also be explained by other factors. For example, the treatment group had to consider an additional attribute in their choices, and work out for themselves what the expected outcomes for air quality and flood would be. As pointed out by Hess and Train (2017), the scale parameter also reflects all other sources of correlation, including scale and preference heterogeneity amongst individual respondents, as these are not separately identifiable.

5.4.3.1 Effect of objective uncertainty on willingness-to-pay

Model 2 (sub-section 5.3.2.2) revealed a strong distaste for objective uncertainty amongst respondents; increasing the level of certainty had a large positive impact on overall WTP. The majority of papers investigating the effect of objective uncertainty on WTP for environmental programmes (i.e. 15 of the 20 reviewed in sub-section 2.3.3) similarly found respondents willing to pay more (and/or more likely to pay) as the likelihood of outcomes improved. For each 1% increase in the probability of benefit delivery, respondents in Southampton were willing to pay an additional £1.38 per household per year. This is similar to the result of Glenk and Colombo (2011) who found respondents willing to pay an additional £1.67 per year for each 1% increase in the probability of programme success. Rolfe and Windle (2010) and Akter *et al.* (2012) found WTP for each 1% increase in the probability of environmental policy success to be even higher, whilst Wielgus *et al.* (2009) found their respondents willing to pay twice as much for guaranteed environmental outcomes than uncertain ones. Southampton respondents' WTP for improving the certainty of urban forest ES delivery may therefore be fairly conservative.

However, respondents in the certain sub-sample were willing to pay significantly *less* for tree planting with implied certain ES delivery, than respondents in the uncertain sub-sample were willing to pay for tree planting with a 70% chance of ES delivery.[74] This could be – as Wielgus *et al.* (2009) and Glenk and Colombo (2011) postulated – because respondents found the objectively uncertain scenario to be more realistic and/or credible than the implied certain one. Respondents were not specifically asked about realism or credibility in the Southampton survey – something

[74] Recall from sub-section 5.3.1 that the certain and uncertain sub-samples were not significantly different from each other in terms of respondent socio-demographics.

that would be useful to ascertain in future studies – nevertheless, the average respondent was only 68% sure that tree planting would reduce air pollution and surface water flooding in Southampton. It is therefore plausible that (some of) those in the control group did not believe the supposedly certain programme outcomes. The propensity of respondents in the certain sub-sample to engage in belief polarisation (as revealed in sub-section 5.3.1.2) supports this postulation; however it should be noted that only 29 of the 339 respondents updated their beliefs in this way (see Table 5.6 on p.154). The effect of subjective beliefs on WTP is discussed in detail in the following sub-section.

Four other studies (none of which elicited respondents' subjective beliefs) have also found evidence of higher WTP for uncertain environmental outcomes. For example, Roberts *et al.* (2008) found WTP for removal of algae from a recreational lake to be more than three times higher for their treatment group (for whom algal blooms occurred with probabilities varying from 0-100%), than their control group (for whom algal blooms occurred or not). Roberts *et al.* (2008) suggested this may be due to the treatment group finding even a small risk of an algal bloom to be unacceptable. Torres *et al.* (2017) found that WTP for conservation efforts to improve the diversity of wetland bird species increased as the likelihood of success decreased. The authors suggested this may be due to respondents adopting a precautionary approach; when outcomes are *inherently* uncertain, it is still better to act than to do nothing.

Posterior analysis suggested respondents' subjective certainty scores for air purification to be a significant (positive) predictor of their WTP for improving objective certainty. Lundhede *et al.* (2015) found a similar result: it was mainly respondents who presumed uncertainty a priori who were put off paying for uncertain improvements. Similarly, Zaalberg *et al.* (2009) found that perceived effectiveness of flood mitigation measures is positively related to people's intentions to invest in such measures. However, there were no socio-demographic factors found to be significant determinants of WTP for improving objective certainty in the present study (despite positive associations with females and those with high education levels). This is not surprising given the lack of consensus in the published literature regarding the relationship between objective certainty and socio-demographic characteristics such as age, gender, education and income (e.g. Akter *et al.*, 2012; Botzen and van den Bergh, 2012; Lundhede *et al.*, 2015; Bartczak *et al.*, 2016; Richert *et al.*, 2017; Faccioli *et al.*, 2018).

5.4.3.2 Effect of subjective uncertainty on willingness-to-pay

The results of RQ3 (see sub-section 5.3.2.3) show that utility for the air purification, flood reduction and objective certainty attributes are each significantly positively affected by respondents' subjective beliefs surrounding the certainty of the delivery of these tree benefits.

Despite this, comparing mean WTP values of Model 3a with Model 3b reveals the only significant difference to be for the Flood attribute. Indeed, controlling for heterogeneity in subjective beliefs regarding ES outcome uncertainty results in significantly lower WTP for reducing residential flood risk, but does not reduce WTP for reducing the number of pollution-related deaths. The different impact on WTP between the two ES appears to stem from the fact that respondents were significantly less confident about the ability of trees to reduce flooding than to reduce air pollution (with posterior beliefs scores of 6.4 and 7.1 respectively).

Few other studies have looked into the effect of subjective uncertainty on WTP for environmental programmes. The first (Burghart *et al.*, 2007) did so without actually eliciting subjective beliefs. To account for the possibility that respondents might have ignored the objective uncertainty attribute and replaced it with their own beliefs, Burghart *et al.* (2007) counter-factually simulated WTP in the absence of this 'distortion'. WTP for a climate change adaptation programme was lower than it would have been if only the provided information informed respondents' choices, suggesting that subjective uncertainty reduced WTP. The second (Akter *et al.*, 2012) found that respondents who perceived a high likelihood of success of climate change mitigation actions were significantly more likely to pay for a mitigation programme. However, as Akter *et al.* (2012) interacted subjective beliefs with the ASC, the impact of subjective uncertainty on WTP for specific attributes is unknown. Next, Lundhede et al. (2015) found that respondents who were a priori certain that a proposed policy would deliver bird conservation outcomes, were willing to pay significantly more for a policy later described as objectively uncertain (via an attribute) than were the other respondents. However, this result of Lundhede et al. (2015) is not directly comparable to RQ3 as dummy variables representing qualitative measures of subjective and objective certainty were used, interacted together. Finally, Adhikari et al. (2017) found that respondents' perceived probability that a proposed forest restoration PES scheme would reduce wildfire risk and thus improve water security significantly positively affected their WTP for the scheme. However, in this case, Adhikari et al. (2017) did not provide respondents with objective probabilities, so the WTP values given by the respondents were based only on prior perceptions.

More studies that look into the effect of subjective uncertainty on WTP are clearly needed. Despite the different methods of these studies, it nevertheless seems that if subjective beliefs are not accounted for – whether in stated preference studies, or real PES scheme proposals – then a significant determinant of choice behaviour remains unidentified, and heterogeneity unexplained. The results of the present study therefore support the assertion by Lundhede *et al.* (2015) that eliciting people's subjective beliefs in addition to providing objective certainty information about a policy is necessary to reduce the random component of utility, and thus the variance of modelled results. A consequence of not doing this might be not knowing why a scheme is rejected

by the public, or, if support is based on misguided confidence about the likelihood of benefit delivery, finding that support is withdrawn when the promised benefits do not materialise (Moffat, 2016). Further research on this topic – both in real PES schemes and in choice experiments – would be useful.

Regression analysis by Akter *et al.* (2012) revealed several categories of respondents to be significantly more optimistic about the likely success of the climate change mitigation scheme than others. These were female respondents (agreeing with the present study), those with higher incomes (the opposite of the present study), those with lower education levels, and those who had heard about the scheme but did not know much about it. Meanwhile, the Southampton study additionally found membership of an environmental organisation, appreciation of the benefits of trees, and support for nature-based solutions to city problems to be significantly positively correlated with subjective certainty regarding the delivery of ES. More studies are needed for any conclusive results on determinants of subjective certainty, however, these two studies suggest that optimism with regards to environmental outcomes may be higher for people with a strong desire to address societal (including environmental) problems. If so, awareness raising about issues such as air pollution, surface water flooding, urban heat islands, and poor physical and mental health, and about the ability of trees to help address these problems, is likely to be necessary to increase both initial WTP and long-term support for an urban forest PES scheme.

5.4.3.3 Effect of combined objective and subjective uncertainty on willingness-to-pay

Model 4 revealed that, compared to WTP for the overall tree planting programme with trusted, objectively certain outcomes, WTP for respondents experiencing objective uncertainty was 5.6% lower (significant at 5%),[75] whilst WTP for those experiencing subjective uncertainty was 11.4% lower (significant at 10%). Both types of uncertainty therefore have a significant adverse effect on WTP for tree planting, with the effect of subjective uncertainty being the larger of the two. Furthermore, there was no significant difference in WTP for the programme amongst trusters shown certain vs. uncertain outcomes. It could be argued therefore that in order to increase WTP for tree planting, more emphasis be placed on educating people about the benefits of trees (on the assumption that this would improve subjective certainty) than on conducting further scientific research (to improve objective certainty), corroborating the recommendations by Ng *et al.* (2015). However, more research on this topic would be useful, as the one other similar study (Lundhede *et al.*, 2015) did not look into this particular effect.

[75] This is different from the Model 1 vs. Model 2 comparison because subjective uncertainty is also accounted for here. Furthermore, 'objective uncertainty' in this context refers only to chosen alternatives with a 40% or 70% likelihood of air quality and flood benefits occurring; not the treatment group per se.

A key purpose of RQ4 was to identify the effect of combined objective and subjective uncertainty on WTP (via hypothesis $H_4 3$). Specifically this tested whether, amongst doubters, WTP is higher for objectively uncertain than certain outcomes – which is assumed would be due to improved realism and credibility over supposedly certain outcomes (Wielgus *et al.*, 2009; Glenk and Colombo, 2011). However, the results of Model 4 did not support this hypothesis – there was no additional WTP (either positive or negative) for the interaction term ObjUncertD*DoubterD. Consequently, Model 4 provides no evidence that WTP of doubters is higher for objectively uncertain outcomes due to improved realism and credibility. Having said that, it was suggested in sub-section 5.4.3.1 that the propensity of respondents in the certain sub-sample to engage in belief polarisation could have contributed towards the low WTP for Model 1 compared to the possibly more credible Model 2. The only other known study to have looked into something similar is that of Lundhede *et al.* (2015), who found that doubters were willing to pay significantly less than trusters in the presence of objective uncertainty. However, Lundhede *et al.* (2015) did not specifically investigate whether information on outcome uncertainty improves the realism/credibility of a scheme, and they did not isolate the effect of the uncertainty attribute for trusters vs. doubters in their model. More research is therefore required to support the as yet unproven hypothesis that objectively uncertain outcomes increase WTP due to improved realism and credibility.

To summarise, objective and subjective uncertainty regarding delivery of ES both had strong, negative relationships with WTP for the proposed street tree planting programme. However, implying that benefits occur with certainty does not necessarily result in higher WTP than when admitting that tree benefits are objectively uncertain, as many people are 'doubters' and evaluate alternatives considering their subjective beliefs about the likelihood of benefit delivery. Further research is needed to confirm the results of this study; nevertheless, it would appear to be worthwhile educating people about ES provision by trees in order to improve subjective certainty. In addition, the fact that respondents were willing to pay a proportionately large sum to improve the likelihood of ES delivery in Model 2 suggests it may also be worth asking citizens to contribute towards the cost of additional research that ensures the right trees are planted in the right places (thus improving objective uncertainty).

5.4.4 **Study limitations**

If the results of a DCE are to be seen as credible and fit for use by policy-makers and other researchers, then it is important that they are valid, reliable, and of sufficient quality, i.e. with as little bias and random variation in WTP estimates as possible (Swedish Environmental Protection Agency, 2006; Johnston *et al.*, 2017; Que *et al.*, 2017). The three main reasons given by

respondents for their willingness to support the proposed tree planting programme – that they want to improve air quality, improve aesthetics, and reduce flooding – suggest that the survey was fit for purpose. As described in sub-section 5.2.3.1, the consequentiality of the proposed scheme was emphasised through the survey in order to limit hypothetical bias (Carson *et al.*, 2014). Though 28% of respondents did not believe that the scheme would be implemented, their WTP was slightly lower than that of other respondents, whilst the overall WTP values were reasonable compared to other studies and existing council tax payments in Southampton. Hypothetical bias is therefore not considered to be a problem for this study. To limit the randomness of choices in the treatment group, the concept of uncertainty was carefully explained, with a question used to test comprehension (answered incorrectly by just 22 respondents).[76] Nevertheless, there are a number of limitations to this study; these are discussed below.

In terms of study results, the sample size of 362 completed sets of choice tasks was smaller than hoped for. The combined postal-online survey method is likely to have dissuaded both citizens who are unwilling to respond to postal surveys and those who are unable to access the internet, whilst the subject of the survey may not have been sufficiently salient. The length and complexity of the survey was also greater than most aimed at the general public, which may be why 13% of those who started the survey did not complete it (though this is not uncommon for choice experiments). Whilst there were sufficient observations to obtain significant results, statistical power was nevertheless reduced, resulting in large confidence intervals around the mean WTP values.

Related to this, the response rate was just 5.6%, and the respondents were not representative of Southampton's population in terms of age or education. If these respondents were more positive about trees than non-respondents, then possible self-selection bias may have inflated the WTP values. For example, posterior analysis of Model 3a revealed significantly higher WTP for reducing the number of properties at risk of flooding amongst older residents. However, in contrast, significantly *lower* WTP was found amongst older respondents for large trees over small trees, whilst no significant relationships were found between education and WTP. Nevertheless, it is important that no attempt is made to aggregate these WTP values for Southampton as a whole (which was not the purpose of the present study) unless the response data is re-weighted to better represent the population (Johnston *et al.*, 2017).

[76] Posterior analysis revealed that these 22 respondents gained significantly lower utility for the ES of air purification than the other respondents ($v = 27$, $t = -2.124$, $P = 0.022$), however, removing them from the dataset made no difference to the coefficient or WTP for AirQ in Model 3a. There were no other differences in utility for this group compared to other respondents; consequently they were retained in the dataset.

In terms of study design, the priors used in the experimental design were not particularly accurate compared to the coefficients obtained from Model 3a of either the pilot study or the main study. This is partly due to a lack of similar urban forest DCE studies on which to base the priors, and partly due to the unrepresentative nature of those involved in the pre-test. For example, compared to the online survey respondents, the (predominantly) highly educated and environmentally-minded participants in the face-to-face interviews and focus groups showed greater interest in reducing the number of pollution-related deaths and in planting large or mixed species of trees, and less concern about ES outcome uncertainty. Johnston *et al.* (2017) recommend that all pre-testing should be conducted using members of the target population, however this was not considered feasible in the time available for the Southampton study. Furthermore, as mentioned in sub-section 5.2.3.2, efficient designs are fairly robust to misspecification of the priors at the time of constructing the design (Rose and Bliemer, 2009). The AirQ, ObjCert and Payment coefficients obtained from Model 3a of the main study lay part way between those used in the experimental design and those derived from the pilot study; a welcome relief regarding the AirQ variable, as this had been insignificant in most of the pilot models. Most of the other coefficients were also not significantly different from zero in Model 3b of the pilot study, though with just 43 respondents, this was perhaps to be expected for a model with so many variables. The coefficients for the Appearance dummies and the ASC were very similar across the two online studies (and thus very different from the priors), whilst the coefficient for Flood was remarkably constant across the experimental design, pilot and main studies.

Variations between the priors and the coefficients from the pilot and main studies could be due to different interpretations of the attributes amongst respondents – despite the researcher's best efforts to minimise such bias. For example, the visual depiction of different tree sizes and species could have been misinterpreted as something else than aesthetic beauty, as large trees tend to be linked with greater provision of ES and disservices than small trees. Meanwhile, whilst describing urban forest-based air purification and stormwater attenuation in terms of 'contributions to people' instead of ES may facilitate comprehension of possibly abstract concepts, the link with urban trees could possibly have been forgotten by some respondents. For example, referring to avoided pollution-related deaths rather than particulate matter absorbed by trees means that other measures of reducing air pollution (such as discouraging vehicle use – as mentioned in the second part of the questionnaire) may have come to mind.

Related to this is the surprising result that for over one-third of respondents, the estimated individual parameter for the air quality attribute was negative, suggesting that they had negative utility for air purification. It could be argued from a face validity perspective that reductions in the

number of pollution-related deaths and the number of properties at risk of flooding should result in strictly positive utility. However, restricting the distribution of the random parameter for the air quality attribute to be positive using a log-normal distribution and a restricted uniform distribution both resulted in considerably worse model fit compared to using a normal distribution (as in the presented model). Whilst the cause may still be statistical (perhaps many observations were only marginally positive), it is possible that these negative estimates reflect either a misinterpretation of the attribute (as mentioned above), or genuine negative attitudes towards air quality improvements. Alternatively, strategic bias could possibly have been caused by the Clean Air Zone consultation which was ongoing in Southampton at the time of the online surveys, as some residents were strongly opposed to proposals to start charging polluting commercial vehicles to enter the city (Rimell, 2018).

Another related limitation of the study is that it remains unclear what drives people's WTP for urban tree planting. Whilst a desire to improve air quality, improve aesthetics, and reduce flooding were the top three of eight reasons given by respondents for their WTP for tree planting, the WTP for air purification and stormwater attenuation were only very small proportions of overall WTP for the tree planting programme (which was dominated by the ASC). Valuing individual ES in a DCE is difficult as the urban forest provides far more ES (not to mention disservices) than it is possible to incorporate as attributes in a choice set without over-burdening respondents and/or causing model convergence issues. It is possible, therefore, that flood reduction and air purification are seen as relatively unimportant compared to other benefits of planting trees that were not included in the experiment.

However, this seems unlikely, as from a list of seven urban forest ES (considered important in other citizen preference studies) that were shown at the start of the survey, air purification was ranked first (though flood reduction was only fifth). Furthermore, the use of dummy variables for the appearance attribute meant the baseline level was confounded with the ASC, so WTP for the ES of aesthetic beauty was not separately identifiable from the overall tree programme. Still, as aesthetic beauty was only the fourth highest ranked ES in this study, it seems unlikely that this is what is driving the overall WTP for the programme. Soto *et al.* (2018) also found a much larger coefficient for their ASC than for their three urban forest ES attributes, though the difference was less pronounced than in the present study. It is possible that decomposing urban forests into their individual benefits is not meaningful for people – perhaps because they consider the ecosystem as a whole, or because of the synergistic relationship between ES and the number of trees (assuming the right trees are planted and managed in the right places) (Davies *et al.*, 2017a). Decompositions into individual ES are common for other ecosystems though – including rural

forests (e.g. Brey *et al.*, 2007; Gatto *et al.*, 2014; Roesch-McNally and Rabotyagov, 2016). More DCE studies that value individual urban forest ES will be needed to investigate this issue further.

This chapter has explored only the effects of outcome uncertainty on WTP; 'preference' or 'decision' uncertainty, found to be important in environmental stated preference studies (Dekker *et al.*, 2016; Voltaire *et al.*, 2017) has not been considered. For example, respondents may have found it difficult to make choices between alternative tree programmes, as this will have required them to make trade-offs that they are not used to making between possibly unfamiliar ES. By failing to account for this uncertainty (and increased randomness) in respondents' decision making, the resulting welfare estimates and WTP values may be biased (Dekker *et al.*, 2016). Accounting for decision uncertainty in choice experiments typically requires asking respondents directly after each choice task how sure they were about their choice, and then incorporating this self-reported decision uncertainty directly into the model as an explanatory variable (Lundhede *et al.*, 2009; Börger, 2015). However, given that the survey already contained questions in relation to two types of outcome uncertainty, it was considered that adding yet more questions relating to uncertainty would be too confusing and burdensome for respondents.

It is also possible that choices could be influenced and WTP biased by asking people for their subjective beliefs regarding likely ES delivery in advance of the choice questions, due to the doubt this could raise in their minds (Hanley *et al.*, 2016a). This could be a particular issue for the control group, who were not provided with any uncertainty information through the scenario. This priming effect cannot be ruled out; a third sub-sample (with respondents shown certain outcomes and not asked about their subjective beliefs) would have been necessary to identify whether the WTP values for Model 1 were affected by the subjective certainty question, but this was not possible within the available budget. Lundhede *et al.* (2015) tested for this issue by asking a set of choice questions both before and after ascertaining respondent's subjective beliefs, finding no evidence of a priming effect. Furthermore, as mentioned in sub-section 5.3.1.2, there was no difference in posterior beliefs between the control and treatment groups (either in terms of the mean subjective certainty score, or the proportion of doubters), so between-group bias is unlikely to have occurred. As Lundhede *et al.* (2015) point out, eliciting posterior beliefs *instead* of prior beliefs would have been problematic, as the former are likely to have been influenced by the choice tasks.

Another limitation was the different way in which the objective and subjective certainty variables were specified in the survey, which made comparing these two different types of outcome uncertainty somewhat difficult. For instance, in Model 4, ObjUncertD and DoubterD were proposed to be equivalent, with ≤70% (or ≤7) representing uncertainty for both variables, and

>70% (or >7) representing certainty. However, whilst it may be reasonable to describe the attribute levels of 40% and 70% objective certainty as 'uncertain' and 100% (or implied) objective certainty as 'certain', it is difficult to justify that a subjective certainty score of 7 out of 10 (averaged across two different ES) implies uncertainty, but that 7.5 out of 10 implies certainty. Similarly, for the purpose of defining a discrepancy between objective and subjective certainty in sub-section 5.3.1.2, 'trusters' (those with prior belief scores of $7 < x \leq 10$), 'weak doubters' (those with prior belief scores of $4 < x \leq 7$), and 'strong doubters' (those with prior belief scores of $0 \leq x \leq 4$) were assumed to be equivalent to the objective certainty attribute levels of 100%, 70% and 40%, respectively.

The study could have been designed differently to avoid this issue – for example, in the study by Lundhede *et al.* (2015), objective and subjective certainty were both described to respondents using the following four categories: 'very uncertain', 'rather uncertain', 'rather certain' and 'very certain'. The disadvantages of this approach are that subjective certainty may be overly constrained with just four categories to choose from, whilst qualitative levels can mean different things to different people. Furthermore, increasing the number of levels for the objective certainty attribute requires a larger experimental design, and thus either more choices per respondent, or a larger sample size. The approach used by Akter *et al.* (2012) was to display the objective certainty levels as ranges (e.g. '33-50% chance', '50-66% chance' and so on). Whilst this would have facilitated determining discrepancies between objective and subjective certainty, with two rather than one ES being described as uncertain in the treatment survey, it was considered that the use of ranges would have caused an unnecessarily high cognitive burden for respondents.

A further limitation relating to Model 4 is the direct inclusion of subjective uncertainty in the utility function (effectively interacted with the ASC). Some authors (e.g. Train *et al.*, 1987; Mariel *et al.*, 2015) argue that attitudinal variables should not be included as explanatory variables in the utility function, as the latent nature of attitudes means that they cannot be measured directly, and so are likely to suffer from measurement error. Furthermore, such attitudinal variables could be correlated with the other modelled variables and/or the error term (due to correlation with unobserved factors), in which case endogeneity bias may occur (Ben-Akiva *et al.*, 2002; Bolduc *et al.*, 2005; Johnston *et al.*, 2017). For example, posterior analysis revealed the subjective certainty variable to be significantly positively correlated with AirQ and ObjCert, and significantly negatively correlated with income and membership of an environmental organisation. Consequently, more complicated hybrid choice models are increasingly being used, whereby attitudinal variables enter the model indirectly through latent variables, which are functions of socio-demographics and an error term (Hess and Beharry-Borg, 2012; Czajkowski *et al.*, 2017; Faccioli and Czajkowski, 2018). However, there does not appear to be any published literature (in terms of applied studies)

proving such an approach to be superior over either including attitudes in the model directly, or using such variables in posterior analysis. Critiques of hybrid choice models also exist, for example, socio-demographic variables are rarely found to be significant in such models due to links with the attitudinal variables (Mariel *et al.*, 2015).

Finally, neither the potential difference in the scale variance between the control and treatment groups, nor scale heterogeneity at individual respondent level were accounted for in the models. As discussed by Hess and Train (2017), respondents who are influenced by external factors when making their choices will have smaller coefficients for each of the modelled variables than will respondents who are unaffected by external factors, resulting in correlated coefficients. Consequently, the statistical significance of the treatment scale parameter in models 3a, 3b and 4, could in fact be caused by other sources of correlation that are picked up by the scale parameter, rather than (or in addition to) the effect of the treatment (Hess and Train, 2017). Allowing for all forms of correlation among utility coefficients is possible (by estimating a model with full covariance), however Hess and Train (2017) concede that this is not an absolute requirement, so long as the limitation is acknowledged. Furthermore, different sources of correlation will still not be separately identifiable.

5.5 Conclusions

This study makes an important contribution to the stated preference literature on environmental outcome uncertainty, by investigating the effect of both subjective and objective uncertainty. In particular, it investigates how people who a priori trust or doubt the provision of urban forest regulating ES react to a proposed tree planting PES scheme with outcomes described as either certain or uncertain. It is also one of the few studies to use stated preference techniques to value the individual ES that could be the focus of such a PES scheme, as opposed to the usual generic bundles of ES.

RQ1 revealed that the majority of respondents to the survey were willing to pay for street tree planting that helps to improve the city's air quality, surface water drainage, and aesthetics. Other urban forest ES of importance to respondents include health and wellbeing, habitat for wildlife, and the provision of shade; however avoiding root damage to pavements was also considered important. Overall there was no specific preference between the planting of small, large, or mixed-species of trees, which should enable local authorities to plant the species considered most suitable for the location and issue(s) to be addressed.

To improve the effectiveness of environmental programmes, previous studies have suggested that outcome uncertainty be acknowledged – even if this reduces initial support for the policy.

Whilst the Southampton study (through RQ2) revealed a strong disutility for objective uncertainty regarding air quality and flood outcomes, there was evidence to suggest that WTP for a tree planting programme with implied certain outcomes is in fact *lower* than one with outcomes presented as uncertain. Though not explicitly investigated, this could be due to cognitive dissonance, resulting from the provision of objective certainty information (implied or stated) that conflicts with people's prior beliefs about the likelihood of ES delivery.

The study revealed respondents to be, on average, 71% confident in the ability of trees to reduce air pollution, and only 64% confident regarding the flood reduction benefits of trees – far below the 100% certain outcomes implied through the survey provided to the control group, or stated as one of three possible outcomes for the treatment group. As a result, RQ3 revealed subjective beliefs to have a significant effect on respondents' utility for improved air quality, flood and objective certainty outcomes, although only WTP for the Flood outcome was significantly reduced when heterogeneity in subjective certainty was accounted for – likely due to the lower level of public confidence in this ES.

Finally, RQ4 showed that subjective uncertainty reduces WTP to a greater degree than does objective uncertainty. Furthermore, compared to the baseline situation of a truster being shown certain outcomes (the assumed situation for most DCEs and PES schemes), WTP for a truster shown uncertain outcomes was not significantly lower, but WTP for a doubter shown certain outcomes was. However, there was insufficient evidence to suggest that a priori doubters react to objective uncertainty more positively than a priori trusters – as might be the case if the former group appreciated the improved realism and credibility of outcomes presented as uncertain.

Overall, the results of this study support the suggestions of others that objective uncertainty should be explicitly acknowledged in PES schemes and other environmental programmes as opposed to implying that ES provision is guaranteed. Furthermore, as particularly low levels of subjective certainty have been found to impact significantly on WTP (i.e. for the Flood attribute), it is worth gauging public opinion about the likelihood of ES delivery in the early stages of scheme design so that action (such as an awareness raising campaign) may be undertaken in advance of the launch of the scheme. In contrast, if subjective beliefs are not accounted for, it may be difficult to determine why a scheme is either rejected outright, or suffers from dwindling support later on in the event that promised benefits do not materialise.

Going forwards it would be useful to conduct research to better understand people's subjective uncertainty regarding ES provision. The majority of citizens are unfamiliar with the concept of ES, and so are unlikely to have strong views on the likelihood of provision of different ES. The negative effect of subjective uncertainty on WTP may therefore be weaker for those who are less

confident about their own subjective beliefs, as found by Akter *et al.* (2012). Cognitive dissonance could also be researched more explicitly in future, to investigate the effect on WTP for environmental programmes of positive vs. negative discrepancies, and particularly large vs. small discrepancies, between objective and subjective certainty. For example, it may be the case that small discrepancies have little impact on WTP, but that large discrepancies result in mistrust of the scheme, and thus lower (or even zero) WTP. Related to this, it would be useful to find out from respondents explicitly whether presenting outcomes as uncertain improves the realism and credibility of environmental schemes. This could involve distinct certain and uncertain sub-samples as used here, or a before-and-after approach with the same group of respondents, where uncertainty is introduced half way into the survey. Finally, further research into citizen (and business) WTP for individual ES would also be prudent, as this will help to determine whether the bundling, stacking or piggybacking of different ES is most appropriate for urban forest PES schemes.

Chapter 6 Discussion and Conclusions

6.1 Purpose of the thesis in the context of the wider literature

The overarching aim of this thesis was to establish whether a public-private urban forest PES scheme could be a feasible approach for addressing the socio-political constraints to delivery of ES in cities, thus improving climate change adaptation and quality of life. This was broken down into three objectives, each underpinned by a literature review (presented in Chapter 2) which revealed a series of knowledge gaps and problems to address. The findings of the literature review for each objective are summarised below.

Objective 1: Establish the extent to which local authorities manage their urban forests for regulating ES provision, and the drivers for, and constraints to, taking such an approach.

The ES literature suggests that socio-political constraints such as institutional failure, information failure, and path dependence, are hindering the mainstreaming of ES into government decision-making and urban planning worldwide. In the specific context of urban forest management, similar conclusions can be drawn for Europe, where there was no indication in the reviewed literature as to whether an ES approach is even an aspiration. Instead, studies reveal that urban forest management suffers from low levels of funding and support from local council staff, businesses and citizens, and poor communication (especially across council departments). However, this is in sharp contrast to the situation in Canada and the United States, where the literature suggests that ES delivery is a key driver of urban forest planning and management. Based on the recommendations of ES studies (particularly those from Europe) and North American urban forest studies, a potential (but largely untested) way of increasing support and funding for urban forest ES delivery might be to focus on creating innovative partnerships between local authorities, citizens and businesses.

Objective 2: Establish how business attitudes towards urban ES affect the way that businesses might approach the financing of trees, e.g. through a PES scheme.

There is very little published information on businesses' ES preferences (either from the academic or grey literature), and scant evidence of business involvement in PES schemes, especially in urban environments. This and the wider CSR literature suggest that, despite the presence of moral incentives, most businesses are only willing to invest in the environment if there is a clear link to the success of their business (either directly or indirectly). The literature suggests that a number of other factors are important if a PES scheme (of any kind) is to be successful. These

include the involvement of all affected parties; trust, understanding and acceptability by key actors (assisted by involvement of an intermediary); ease of implementation (again assisted by involvement of an intermediary); flexibility around changing conditions; a lower cost than alternative policies; and verified, additional provision of ES/benefits. However, a number of studies find this last point is somewhat aspirational. The cost and complexity of monitoring additional provision of ES means that PES schemes are often based only on assumed ES provision relating to changes in land management. It is unclear from the literature whether decision-makers and buyers are aware of the uncertainty surrounding ES provision, and if not, what impact this information might have on their willingness to invest in such a scheme.

Objective 3: Establish how the willingness-to-pay (WTP) of citizens for provision of urban forest ES is affected by public preferences and values, and the objective and subjective uncertainty surrounding ES delivery.

Aesthetic beauty is by far the most highly ranked urban forest ES across the identified citizen preference studies, followed by heat amelioration, air purification, and habitat for wildlife; with stormwater attenuation down in tenth place from a list of 28 identified ES. However, citizen WTP for these urban forest ES is largely unknown, as only two stated preference studies on urban forests were found that explicitly value individual ES. The remainder ascertain citizen WTP for urban forest enhancement more generally, which typically implies guaranteed provision of a bundle of unquantified ES. Outside of the urban forest literature, a number of stated preference studies look at WTP for environmental schemes with outcomes presented as uncertain rather than certain. In line with 'expected utility theory', respondents in these studies are willing to pay less (and less willing to pay) for outcomes (objectively) presented as uncertain. However, there is a lack of research investigating whether people have doubts about the likely delivery of ES (i.e. 'subjective' uncertainty); and thus whether acknowledging 'objective' outcome uncertainty could enhance rather than reduce interest in PES schemes.

6.2 Key findings from the three papers

Paper 1: Challenges for tree officers to enhance the provision of regulating ES from urban forests (Davies *et al.*, 2017b)

Using in-depth interviews with the local authority tree officer from 15 of Britain's most densely populated cities, Paper 1 is the only known published study (at the time of writing) to investigate consideration of ES in UK urban forest management. The findings corroborated the anticipated concerns raised by the literature review: Britain's urban forests are very rarely planned or

managed with ES provision in mind. According to the interviewed tree officers, this is due to: limited support from – and understanding of ES amongst – councillors, council departments, and the general public; a lack of local strategic policy for trees and other green infrastructure; and declining local authority tree budgets.

Consequently, and based on suggestions from the interviewed tree officers, the paper recommends three measures to facilitate an ES delivery approach within public sector urban forest management:

a) Awareness-raising amongst senior council staff, citizens, and businesses, by means of obtaining and publicising a comprehensive evidence base on local ES delivery and associated monetary values (e.g. through an i-Tree study) – helping to address 'information failure';
b) Strategic planning, through developing and publishing an urban forest strategy that incorporates targets for ensuring the right tree is planted and managed in the right place for ES delivery – helping to address 'path dependence'; and
c) Increasing financial contributions for tree planting and maintenance by those who benefit from the provided ES, using novel partnerships such as public-private PES schemes – helping to address 'institutional failure'.

The rest of the thesis focused on this third recommendation.[77] Using the UK city of Southampton as a case study, the second and third papers investigated the feasibility of developing an urban forest PES scheme funded by businesses and citizens respectively.

Paper 2: Business attitudes towards funding ES provided by urban forests (Davies *et al.*, 2018)

Using questionnaire-based interviews with 30 businesses from the Southampton area, Paper 2 is the only known published study (at the time of writing) to have investigated business attitudes towards investing in an urban forest PES scheme. The paper found 90% of business respondents to be in favour of private sector investment in urban forests, with particular interest shown in contributing to enhancing air purification, stormwater attenuation, aesthetics, and employee health and wellbeing.

[77] The first and especially the second recommendations have since featured in the UK government's Urban Tree Manual (Barbrook *et al.*, 2018), as well as a consultation document on protecting and enhancing England's urban trees and woodlands (Defra, 2018c). These emphasise the importance of local authorities developing Tree and Woodland Strategies based on quantified and monetised ES provision, and planting the right tree in the right place to enhance ES provision. Neither document discusses urban forest funding or partnership working.

Whilst the environmental and social benefits of urban trees dominated the interest of some respondents, the paper agreed with Koellner *et al.* (2010) and Meißner and Grote (2015) that intrinsic or relational motivations alone are insufficient for a PES scheme to work. Most businesses would prefer to donate on a voluntary basis to specific projects located in the vicinity of their business premises, as this would enable them to benefit in ways which would not be possible from a mandatory scheme – both directly (e.g. from improved employee health), and indirectly (e.g. improving their reputation via marketing and CSR). Similar results have since been found by Krause and Matzdorf (2019).

Before entering a PES scheme, most businesses would require examples of similar schemes where businesses or the wider community have benefitted – found also by Bennett *et al.* (2014) and Eves *et al.* (2015). For the operational phase, transparency, input-based conditionality, and cost-effectiveness were all considered important. In other words, as buyers, businesses would want confirmation of the numbers, locations and survival of the trees they paid for, as well as information on the scheme overall.

Paper 3: Citizen WTP for an urban forest PES scheme with uncertain outcomes

Using a discrete choice experiment (DCE) with 362 residents of Southampton, Paper 3 is the only known study (at the time of writing) to have used a stated preference technique to a) value urban forest-based air purification and stormwater attenuation; and b) ascertain the effect of ES outcome uncertainty on support for urban forest enhancement. Similar to the findings of Paper 2 and other citizen WTP studies, Paper 3 revealed that 93% of respondents were in favour of contributing financially to an urban forest PES scheme. However, preferences for urban forest ES were slightly different compared to the existing literature, with air purification the most highly ranked ES, followed by contributions to health and wellbeing, habitat for wildlife, aesthetic beauty, stormwater attenuation, and heat amelioration. WTP for urban forest-based stormwater attenuation and air purification were each found to be positive and significant. Depending on the choice model run, mean WTP values per household per year ranged from £6.08 to £10.48 for air purification (per one avoided pollution-related death), and from £2.30 to £9.39 for stormwater attenuation (per 100 fewer properties at risk of surface water flooding). However, these figures are low compared to the mean WTP for the PES scheme overall; for example, Model 1 (without uncertainty) revealed mean WTP of £140 per household per year, equivalent to an 8% rise in council tax for the average property in Southampton. This perhaps suggests that respondents value trees as an overall package (encompassing combined intrinsic, instrumental and relational values) rather than in terms of their individual benefits.

The main focus of the third paper was how citizen WTP is affected by environmental outcome uncertainty. The finding of Paper 3 that respondents have strong disutility for 'objective' uncertainty (i.e. uncertainty information provided by an authoritative source) regarding air quality and flood outcomes was to be expected from similar studies. Despite this, WTP for a tree planting programme with implied certain outcomes was lower than one with outcomes presented as occurring with 70% certainty. This is due to the influence of 'subjective' uncertainty (i.e. people's prior beliefs about the likelihood of ES delivery) – expected to be the paper's greatest contribution to the literature. On average, respondents were 68% confident about the delivery of the two regulating ES (though this varied across individuals from 0% to 100%), and these subjective beliefs were found to have a significant effect on respondents' utility for improved air quality, flood and objective certainty outcomes. Furthermore, compared to the mean WTP for the PES scheme overall amongst respondents for whom ES outcomes were both objectively and subjectively *certain*, mean WTP was 11% lower for respondents with *subjective uncertainty* over ES outcomes, but just 6% lower for those with *objective* uncertainty. This suggests that respondents prioritised their own (uncertain) subjective beliefs about ES provision over the supposedly certain (or objectively uncertain) outcomes. However, there was insufficient evidence to suggest that people who doubt ES delivery react to objective uncertainty more positively than those who trust it. Thus the suggestion that acknowledging outcome uncertainty increases WTP for PES schemes through enhanced realism and credibility was not supported.

6.3 Discussion and reflections

Despite the prevalence of scientific and grey literature on the social, economic and financial benefits of green infrastructure, a number of socio-political constraints continue to restrict the mainstreaming of ES in urban planning worldwide. In particular, financial constraints and poor communication both within local government and externally with businesses and citizens, are hampering urban tree planting and ES-focused urban forest management in Europe. Through Objective 1, this thesis has confirmed that consideration of ES in urban forest planning and management is the exception, not the rule. Given the worsening socio-environmental problems that cities face as their populations grow and the climate changes, it is surprising that innovative funding mechanisms and partnerships for the provision of urban ES have not been researched.

This thesis sought to address this gap. The overarching knowledge contribution of this thesis is the finding that businesses and citizens are willing to contribute financially to enhanced provision of urban ES (in partnership with local authorities) by means of a PES scheme. Business attitudes towards urban forest ES were previously unknown, and it is likely that local government staff

worldwide share the perception of those interviewed for Objective 1 that businesses are not concerned with such matters. The finding of this thesis that businesses have a strong interest in contributing to enhancing air purification, stormwater attenuation, aesthetics, and employee health and wellbeing in their local area is therefore an important one. Citizen interest in funding individual urban forest ES has also barely been researched, with just two papers revealing WTP for heat amelioration and property price uplift (Morawetz and Koemle, 2017; Soto *et al.*, 2018). The finding of this thesis that citizens have significant positive WTP for the air purification and stormwater attenuation benefits of urban trees – with a desire to improve aesthetics also driving their support for a PES scheme – is therefore also of importance.

This thesis additionally provides important new information on the preferences of potential urban PES scheme buyers. Interviewed businesses would prefer to invest voluntarily in specific local projects with transparent processes and quantified outcomes, for a mixture of intrinsic, instrumental and relational reasons – findings since corroborated by Krause and Matzdorf (2019). Meanwhile, the finding of Objective 3 that people's subjective uncertainty around ES provision has a greater negative impact on their WTP for tree planting than does objective information on uncertainty provided alongside the other PES scheme details is especially valuable. As well as having practical implications for the design and success of a PES scheme, this finding has particular implications for future academic studies, as discussed below in section 6.4.

In addition to these key contributions to knowledge, it is worth discussing in more detail the themes of 'uncertainty' and 'values' which run through this thesis, as they are especially relevant in the context of stakeholder understanding and funding of ES delivery, and the ability of stakeholders to work together as a partnership. This links back to the conceptual framework for an urban forest PES scheme introduced in sub-section 1.2.2, which shows how uncertainties are present at every step of the process, and that the variety of different values held by urban stakeholders both influence and are influenced by preceding and subsequent steps. The themes of uncertainty and values are discussed in turn, below.

6.3.1 Uncertainty

The uncertainty surrounding nature-based solutions to city problems (be that ecological, livelihood, knowledge, socio-political, or decision uncertainty) is a common thread throughout this thesis. Some of the literature reviewed in sub-section 2.1.3 suggests that uncertainties around ES delivery are restricting proactive decision making (Turner and Daily, 2008; Foster *et al.*, 2011; Ojea, 2015). However other authors argue that evidence on ecosystem-based adaptation is sufficient, but is being ignored at local authority level due to a resistance to change (Naumann *et*

al., 2011; Matthews *et al.*, 2015; Wamsler, 2015). The interviewed tree officers had no doubts that planting the right tree species in the right locations would alleviate the impacts of heatwaves, intense rainfall, and air pollution in their cities. For them, achieving this is a matter of persuading budget holders and external stakeholders to invest in their urban forest by quantifying and valuing its provision of ES. However, a number of the interviewed tree officers shared the popular yet overly simplistic view that provision of (all) ecosystem services can be enhanced simply by increasing canopy cover. Such an approach would not only fail to maximise ES provision, but would likely cause trade-offs amongst ES, with the result that fewer benefits are delivered than expected (Bennett *et al.*, 2009; Moffat, 2016; Salmond *et al.*, 2016). Uncertainties surrounding ES provision thus appear to be unaccounted for by practitioners.

Where beneficiaries are paying for the delivery of ES, inadequate understanding of the links between land use/management and ES delivery by land owners/managers can have repercussions for people's long-term support of such schemes (Moffat, 2016; Lima *et al.*, 2017). Sub-section 2.2.4 of the literature review revealed that most PES schemes are indeed centred on input-based conditionality with assumed rather than proven links to ES, and furthermore, that information on outcome uncertainty is perhaps not being disclosed to (all) PES participants (Glenk *et al.*, 2014; Hamel and Bryant, 2017; Lima *et al.*, 2017). Thompson (2018) suggests that businesses *are* aware of the uncertainties surrounding ES delivery, but choose to accept or ignore them – possibly as they consider the marketing and CSR benefits of PES schemes to be more important than the increased ES provision. The businesses interviewed for this thesis showed little awareness of the uncertainties surrounding delivery of ES, and generally wanted monitoring only of inputs (i.e. the number of trees planted and surviving). Three respondents – each of whom would invest without any monitoring at all – mentioned that trying to prove or value the ES delivered by tree planting would likely be expensive, complex and subjective, and thus unnecessary. A study by Waylen and Martin-Ortega (2018) revealed UK environmental professionals want more research regarding when and how to act regarding ES outcome uncertainty in PES schemes. Consequently, the study suggests that PES may be seen as more suited to where there is "certainty about how ES are supplied, and where they are relatively easily defined and measurable" (p.25).

Objective 3 of the thesis investigated perceptions around outcome uncertainty in more detail. The literature reviewed in sub-section 2.3.3 suggested that if outcome uncertainty is not disclosed to potential buyers, decisions may be biased in favour of the scheme, with buyers later withdrawing their support if the promised benefits do not materialise (Wielgus *et al.*, 2009; Glenk *et al.*, 2014; Moffat, 2016). Conversely, those who suspect outcome uncertainty will base their decisions on their own subjective beliefs instead (which will be unknown to the scheme organisers or researchers), and may even view the scheme as unrealistic (Wielgus *et al.*, 2009; Glenk and

Colombo, 2011; Lundhede *et al.*, 2015). The choice experiment with Southampton citizens confirmed that, while people prefer higher levels of outcome certainty, their subjective beliefs regarding air purification and stormwater attenuation (i.e. that delivery of these ES is on average only 68% certain) have more influence on their WTP for tree planting than 'objective' (un)certainty information. Consequently, failing to acknowledge that the outcomes of a PES scheme may be uncertain will not necessarily result in greater support for it.

The political, economic and environmental uncertainty associated with the changing climate and urbanizing population is increasing the need for innovative and adaptive governance institutions for the management of natural resources and public goods, focused on resilience and cooperation (Bhagwat *et al.*, 2017; Steenberg *et al.*, 2019). This is why a public-private urban forest PES scheme could be so useful. A flexible, long-term approach to urban forest management that acknowledges uncertainties and involves all interested stakeholders in funding and decision-making is likely to be far more resilient to political, economic and environmental shocks (Lawrence, 2017; Steenberg *et al.*, 2019).

6.3.2 **Values**

Another common thread through this thesis is that of values. As discussed in section 1.1.6, there is increasing debate about values in relation to socio-ecological systems (Mace *et al.*, 2011; Piccolo, 2017; Chan *et al.*, 2018). This relates to the notions of individual vs. shared instrumental values (relating to direct, indirect or non-use of ES), intrinsic values (the value of nature for its own sake), and relational values (encompassing preferences, principles and virtues 'about nature' and 'of nature'). Meanwhile, different people attach multiple meanings and viewpoints to urban ES (Hubacek and Kronenberg, 2013; Sander and Zhao, 2015), and the values people hold play a significant role in explaining their behaviour (de Groot and Steg, 2008).

As custodians of their cities – though admittedly with limited scope and little resource – local authority tree officers are concerned with doing what is best for the environment and societal wellbeing. Elements of shared instrumental values, intrinsic values, and relational values were apparent in their interview responses, opinions and described activities. However, the interviewed tree officers did not imagine that either citizens or businesses would share such societal or environmental values. Based on the complaints they receive about tree disservices, the tree officers perceived both groups as, at best holding individual instrumental values for trees relating to aesthetics, but more likely holding either negative values, or no values at all – especially not for the wider, public benefits of trees. Such perceptions – especially if shared by council leaders and others with decision-making power – may help to explain the nationwide

decline in council tree planting budgets, as well as the removal of thousands of street trees in the UK city of Sheffield without any public consultation (which – conversely – has since resulted in a large scale public backlash) (Burn, 2018).

In contrast to the negative perceptions of the interviewed tree officers, the results of the second and third papers concur with the public's reaction in Sheffield and the literature on tree preferences (discussed in sub-section 2.3.1), in that both businesses and citizens rate the benefits of trees as significantly more important than the nuisances. The greatest nuisances that Southampton's urban trees pose to citizens (damage to infrastructure by tree roots) and businesses (animal excrement and obstructed business signs) were considered important by just 51% and 43% of respondents, respectively. Conversely, air purification was considered important to 96% of citizens and 90% of businesses, making it the highest and second-highest ranking ES in the two studies. As suggested in sub-section 5.4.1 of this thesis, the strong interest in addressing air pollution is likely caused by the recent consultation on the council's proposed 'Clean Air Zone' (Southampton City Council, 2018), preceded by years of local media attention on the subject (Franklin, 2016; Rimell, 2018). In contrast to the majority of the citizen preference studies reviewed in sub-section 2.3.1, citizens in Southampton rated stormwater attenuation *above* heat amelioration. This is hard to explain based on actual weather events in the city, as whilst there had been severe local flooding in Southampton earlier in the year (Daily Echo, 2018), there had been a more recent prolonged heatwave (Hampshire Chronicle, 2018). However, the result is not surprising given the results of Objective 1 and Objective 2 – there was a sense among both the local authority tree officers and the businesses that, compared to other ES, heat amelioration is less tangible, and less useful in Britain's (currently) cool climate.

Half of the businesses interviewed for Objective 2 said they would invest in the proposed PES scheme because they considered it their moral duty to support their local environment or community. Meanwhile, a desire to improve Southampton's air quality was the primary reason citizens gave for being willing to pay for tree planting (though this may not apply in less polluted cities). These are similar to the findings of others (e.g. Koellner *et al.*, 2010; Obeng and Aguilar, 2018; Thompson, 2018) that awareness of the impacts of environmental degradation on societal wellbeing can be a strong driving factor in both citizens' and businesses' willingness to contribute to PES schemes. Though in contrast to the perceptions of the interviewed tree officers, in the context of the broader literature, the promising results of Objectives 2 and 3 are not a surprise. Indeed, the concept of public value (i.e. doing good for society) is no longer limited to the public sector, and exists throughout all types of organizations and community networks (Ayres, 2019). As suggested elsewhere in this thesis, and in studies on public value (Bryson *et al.*, 2017; Ayres, 2019), public-private-civic partnerships between the beneficiaries of ES are a useful way of

promoting shared and relational values, and are necessary to solve the growing problems cities face.

However, whilst moral motivations for the funding of tree planting may be desirable, they are unlikely to be sufficient on their own. Indeed, Rode *et al.* (2017) found both moral-ecological and monetised anthropocentric ES arguments together increased citizen support for environmental protection more than either argument alone. Meanwhile, the primary motivation for businesses to invest in the proposed urban forest PES scheme in Southampton was to enhance their reputation, and thus attract new (or retain existing) customers, clients and staff. The importance of individual instrumental values should therefore not be underestimated; indeed, it is these values which ought to be most strongly promoted by those wishing to set up a PES scheme if the majority of citizens, and particularly businesses, are to support it.

Furthermore, it has been suggested by a number of authors (e.g. Kosoy and Corbera, 2010; Kallis *et al.*, 2013; Rode *et al.*, 2017) that the moral willingness people have to contribute to society and the environment may be undermined – or 'crowded out' – by putting a monetary value on ES and asking people to pay for them in a market setting (the so called 'commodification' of nature). Of course PES schemes do not necessarily require the monetisation of nature, as beneficiaries may contribute towards the cost of management and maintenance of environmental assets irrespective of the ES they provide (Martin-Ortega and Waylen, 2018). Nevertheless, once a PES scheme has been introduced, citizen and business buyers may start to consider it as just another expense/tax (towards which resentment starts to build), whilst focusing more on the cost-effectiveness of the scheme than the environmental effectiveness. Alternatively, they may begin to see only the benefit that they are paying for, with other (unquantified or non-monetised) benefits forgotten – perhaps resulting in the suppression of other types of value (Kallis *et al.*, 2013). Another possible outcome is that buyers may consider their PES contributions as some sort of 'environmental redemption', allowing them to reduce their participation in further conservation activities (Igoe, 2013; Chan *et al.*, 2017).

Whether the seemingly strong moral motivations of the interviewed businesses and citizens towards investing in environmental enhancement may be crowded out by the introduction of a PES scheme, it is not possible to say at this early stage. Eight of the interviewed businesses (27%) currently voluntarily undertake habitat creation or enhancement activities, whilst a further ten (33%) engage in activities such as promoting environmental practices to others. Whilst the habitat-related activities could feasibly come to an end if an urban forest PES scheme was introduced, it is more likely that environmental promotion activities would *increase*. It is also hard to imagine many of the 54 surveyed citizens (13%) who are members of environmental

organisations giving up their memberships just because they start paying in to a PES scheme. Nevertheless, it would be useful to monitor the attitudes and other environmental activities of PES scheme participants at regular intervals, followed by further awareness raising if required, as people's (potentially changing) preferences and values will have strong implications for the ongoing viability of a public-private urban forest PES scheme (Muradian *et al.*, 2010; Chan *et al.*, 2018).

6.4 Implications for research, policy and practice

Implications of findings for other researchers

The most important methodological contribution of this thesis relates to the inclusion of objective and subjective uncertainty in choice modelling. The thesis supports the recommendations of several other authors who have used stated preference studies to value environmental programmes (e.g. Wielgus *et al.*, 2009; Glenk *et al.*, 2014; Lundhede *et al.*, 2015) that such studies must elicit respondents' subjective beliefs as well as providing objective information on outcome uncertainty if they are to capture valid results. This is important firstly for the validity of the research itself, as uncaptured subjective beliefs could influence respondent choices in ways that are unexplained by the models, potentially biasing WTP estimates. Secondly, it is important for policy-makers and practitioners who may base their schemes upon such research to not only avoid being accused of misleading the public, but to know how potential buyers may respond to information on outcome uncertainty. It is therefore recommended that future (stated preference) studies used to ascertain WTP for environmental programmes acknowledge both objective and subjective uncertainty in the delivery of the proposed programme outcomes.

Secondly, despite the rapidly growing number of publications on the subject of urban ES – including citizen preference studies – there is a scarcity of academic and grey literature investigating attitudes towards and consideration of urban ES amongst businesses worldwide, and amongst local authority staff in the UK and Europe. These groups have arguably the greatest potential to fund and manage the necessary increase in ES provision in an increasingly urban and climate-affected world. This thesis is the first study to address this gap, and further research is needed. Thirdly, the proportionally low WTP for the specific ES of air purification and stormwater attenuation in paper 3 means it remains unclear as to whether payments for individual vs. bundles of ES are most appropriate in an urban forest context. This also requires more research.

Implications of findings for local government policy

An underlying purpose of the thesis was to identify how ES can be integrated into local authority urban forest management – relevant to cities in the UK and elsewhere in Europe. As revealed in sub-section 3.4.4 this requires tree officers to develop action-based urban forest strategies with ES delivery at their core, e.g. as practised in North America, and advised by the UN FAO (Salbitano *et al.*, 2016) and Defra (2018c). If – as experienced by one interviewee – councillors will not support the publishing of an urban forest strategy, then awareness-raising of the ability of trees to help address pressing challenges (e.g. flooding, heat islands, and air pollution) will be required in advance. Existing academic and grey literature (including published i-Tree Eco reports from other areas) can be drawn upon in the first instance, ideally supported by monetised local ES evidence obtained through new i-Tree Eco studies. Simpler valuation methods such as CAVAT can also be used to show councillors, other council departments, citizens and businesses that trees are assets rather than liabilities, by putting a monetary value (a common, and easily understood metric) on the amenity value of the public tree stock. Indeed, CAVAT valuations are increasingly calculated within proprietary tree management software (Doick *et al.*, 2018).

Whilst monetising local ES delivery may result in an increase to local authority urban forest budgets – as has occurred in numerous US cities, as well as several locations in the UK (Soares *et al.*, 2011; Hall *et al.*, 2018)[78] – it may also pique interest from citizens and businesses. Indeed, public-private PES schemes to pay for societal benefits should also be considered as part of the urban policy mix. Waylen and Martin-Ortega (2018) found a desire amongst UK environment professionals to see more PES schemes in future, in part due to the potential for PES to protect "more types of places and ecosystems, especially in urban settings" (p.25). The UK government's new 25 Year Environment Plan pledges to replace the Common Agricultural Policy with a publicly-funded rural PES scheme, whilst private payments for ES will also be 'explored' (Defra, 2018a). The only reference in the 25 Year Environment Plan to developing innovative funding for *urban* ES is through the government-led 'Greater Manchester Urban Pioneer'. This is a pilot study which seeks "investment, time and resources… from the private, public and third sectors" in order to enhance the conurbation's natural capital (Nature Greater Manchester, 2019: online). It is thus unlikely that local authorities will promote urban PES through their strategic planning policy documents until additional research and pilot studies have been undertaken.

[78] As revealed by Hall *et al.* (2018) there are also numerous examples where i-Tree Eco studies in the UK have had seemingly no effect on political support or council funding of the urban forest. For example, due to limited council resources, the i-Tree Eco report for Southampton (Mutch *et al.*, 2017) received no publicity – either within the council itself, or externally amongst citizens and businesses.

Implications of findings for on-the-ground practice

The results from Objectives 2 and 3 of the thesis show that a user-financed urban forest PES scheme has potential to increase funding for urban forests, and so should be trialled by proactive local authorities or intermediaries (e.g. Trusts such as TreeTime Edinburgh (2015)). A recent example of this is 'Plant Your Postcode' which seeks funding from businesses and community groups to plant trees on council-owned land in the UK city of Brighton (CPRE Sussex, 2019). This scheme is run by the pressure group 'Campaign to Protect Rural England' (CPRE), with grant funding from the National Lottery and a local Community Fund. However, if no central government or other external support is available, schemes can be piloted on a smaller scale, for example focusing on the city centre or within business improvement districts. It should be noted that PES schemes are not just about bringing in additional financial resources for the enhancement of natural capital and the ES it provides. The development of such a scheme should also seek to aid understanding of urban forest ES (and the uncertainties related to these) amongst businesses and citizens; elicit the expectations of all PES actors (including subjective beliefs around ES delivery); and improve partnership working between the public, private and civic/community sectors (Martin-Ortega and Waylen, 2018).

In terms of on-the-ground urban forest management, the results of Objectives 2 and 3 may also give local authority tree officers the confidence (though not the funds) to focus on delivering benefits instead of reacting to complaints. Citizens and businesses may not contact the council to congratulate them on their urban trees, but as this thesis has shown, trees *are* valued by these groups, and awareness and appreciation of the regulating and cultural services that trees provide is growing. Even for people who do complain about trees, some of the interviewed tree officers have already found that responding to complaints with scientific and monetary facts and figures about the benefits of trees (drawn from existing reports and articles) can help to change people's perceptions (see Table 3.4 in sub-section 3.3.4).

6.5 Limitations of the overall study

Three types of limitations have been identified for this thesis: firstly, the extent to which the results are generalizable; secondly the challenges encountered with the chosen methods; and thirdly, key topics of relevance to the overall study that have not been explored in this thesis. These are discussed in turn, below.

6.5.1 Applicability of the results

The socio-political constraints to mainstreaming ES in urban planning are evident worldwide – particularly in Europe, and to a lesser extent in North America. By exploring potential solutions to these problems only in the context of UK urban forestry, and specifically in just one city, the findings of the study may not be generalizable to other cities and countries or other green infrastructure contexts. Given the exploratory nature of the study requiring a detailed understanding of stakeholder perspectives, motivations and concerns, it was not appropriate to include multiple case studies. Attempts have therefore been made to discuss the results in the context of the broader literature wherever possible. It is considered that these results are relevant beyond the case study (urban forests in Southampton) to broader urban green infrastructure ES provision in Europe, and potentially throughout the temperate, developed world.

Furthermore, small sample sizes combined with low response rates (just 54% of the 28 local authorities, 30% of the 84 businesses, and 6% of the 6,500 citizens contacted took part in the studies), and the significant over-representation of larger businesses, and older, more educated citizens in the Southampton-based studies may have limited the applicability of the findings. The strong positive attitudes towards enhancing ES provision amongst these three stakeholder groups could therefore be due in part to response bias. Those who did not take part in the research (representing the majority of the UK's local authorities, and the vast majority of Southampton's businesses and citizens) could have less positive attitudes. This has implications for the feasibility of developing an urban forest PES scheme, and requires additional studies to be undertaken elsewhere to confirm the findings.

6.5.2 Methodological limitations

There were also some challenges regarding the methods used for data collection and analysis – particularly for the second and third papers. Objective 2 was met using a combination of qualitative and quantitative approaches, however the sample size was insufficient for (many) significant statistical results. As such the study was generally unable to link responses with business characteristics (e.g. relating to size and sector). Furthermore, the findings of Koellner *et al.* (2010) and CLES and TWT (2015) that some businesses are reluctant to devote time to research studies meant that the interviews were kept short and based around the questionnaire. As a result, in-depth discussion around businesses attitudes (e.g. reasons behind these attitudes) was not possible, and so qualitative results were also limited. As stated in Chapter 4, this was a small and exploratory study – necessary to start addressing an important gap in the literature, but

insufficient to fill it. Since the publication of Paper 2, a similar study has been undertaken in Germany. Krause and Matzdorf (2019) undertook detailed interviews with representatives of 26 businesses, and have attempted to draw conclusions based on business sector.

With Objective 3, stated preference valuation techniques are known to be complex and time consuming, both for the respondents and the researcher (Kanninen, 2006). To avoid over-burdening respondents (particularly for unfamiliar and/or complex goods as in the case of this study) and over-complicating the models, it is sensible to restrict the number of attributes (Pearce *et al.*, 2002; Johnston *et al.*, 2017) – those reviewed in section 2.3 typically had around four. With necessary attributes being objective certainty and the payment vehicle, this meant only two of the three regulating ES that are a focus for this thesis could be included in the DCE – heat amelioration had to be dropped. A brief and simple questionnaire is also necessary to reduce the burden on respondents (particularly when there are lots of complicated choice questions, as was the case here). Thus it was considered unwise to ask many of the attitudinal questions posed in other DCE studies, for example, how sure respondents are when stating their prior and posterior beliefs; whether they have been personally affected by extreme weather events or pollution; or their perception of their local tree cover. In particular, given the preference amongst interviewed businesses for a voluntary payment scheme, and the findings of Mell (2018) that tax-based funding of green infrastructure is unpopular and overly complex, it would have been useful from a policy-perspective to gauge citizen preferences regarding the volunteering of time and/or money instead of compulsory contributions to a tax-based 'City Tree Fund'.

Finally, one of the biggest complaints about the use of stated preference methods is their hypothetical nature, resulting in respondents stating WTP values higher than they would really pay – known as hypothetical bias (Hensher, 2010; Rakotonarivo *et al.*, 2016; Johnston *et al.*, 2017). It was thus necessary to use a compulsory, tax-based payment vehicle, because voluntary payments are more likely to result in unrealistic respondent choices. Two other measures were also used to reduce hypothetical bias in the DCE: describing the tree planting programme so as to appear consequential to respondents (Carson *et al.*, 2014), and reminding them to consider their budget constraints (Bateman *et al.*, 2002). A question asked after the choice tasks revealed that, whilst 28% of respondents did not believe that the tree planting programme would go ahead, their WTP was slightly *lower* than that of other respondents for each of the attributes, meaning that there was no upward bias. Meanwhile, the WTP value of £140 per household per year for Model 1 is within the range of those reported by the urban forest stated preference studies reviewed in sub-section 2.3.2; is just 0.6% of the mean household income in Southampton; and would be equivalent to a council tax increase of approximately 8% for the average Southampton

property. Consequently, hypothetical bias is not thought to have artificially raised the WTP of Southampton citizens for the proposed tree planting programme.

6.5.3 Relevant topics not explored in this thesis

This thesis is also limited by aspects not covered due to their falling out of scope for a focused, time-limited study such as this. For example, increasing ES provision from *privately* owned land and trees (e.g. through tax incentives to plant trees and avoid soil sealing in private gardens and business premises) was not addressed. With anywhere from 25-75% of a city's urban forest being in private ownership (Doick and Davies, 2016), this is equally important for improving quality of life and adaptation to climate change. Enhancing ES provision from private as well as publicly-owned urban land is likely to require a spatially-coordinated, 'landscape' approach whereby different landowners work together, as increasingly being promoted in rural areas (Hanley *et al.*, 2016b; Sheremet *et al.*, 2018). Addressing other urban problems such as deficiencies in physical and mental health and wellbeing of citizens, or nature connections, through enhancing provision of cultural ES is another important consideration not addressed by this thesis.

The issue of transaction costs, along with the policy, governance and legal aspects of PES schemes, have also not been addressed. The details of how an urban, public-private scheme would be set up and managed in practice are yet to be determined. Indeed, environment professionals surveyed by Waylen and Martin-Ortega (2018) have called for additional research into governance processes for enabling PES in the UK, e.g. relating to the possible roles of regulation, taxation, public-private partnerships, intermediaries, and negotiation between parties. The transaction costs around setting up PES schemes are a particular challenge, as tree officers are already so short on time and money. For example, whilst Southampton City Council was sufficiently interested in the results of the second paper to call a meeting with the researcher on the subject, the conclusion was that the Council would support such a scheme if it was business-led, but could not lead on it themselves due to capacity and financial issues (Cllr Rayment, 2018). Similarly, one of the interviewed tree officers questioned who would broker the payment in an urban forest PES scheme. By engaging with each of the stakeholders separately, the issue of who would lead such a programme has not been addressed. As suggested by the literature (e.g. Sattler *et al.*, 2013; Hausknost *et al.*, 2017) and evidenced by tree planting schemes in the UK (TreeTime Edinburgh, 2015; CPRE Sussex, 2019), engaging with possible intermediaries from the third sector is likely to be important for PES success.

Finally, the issue of fairness – in terms of who pays for ES and who benefits from them – was raised by a minority of tree officers and business respondents, but has not been explored in any

detail in this thesis. For example, whilst 27% of the business respondents acknowledged that trees should be planted in areas of need and/or where they are best suited to avoid benefitting only the richer areas of Southampton – supporting the recommendation of Dobbs *et al.* (2014) – 60% of the businesses would prefer the trees they fund to be planted in the vicinity of their business premises to ensure that they are the ones benefitting. There is a risk then that trees planted through voluntary PES schemes may largely benefit the wealthy, representing distributive injustice (Sommerville *et al.*, 2010; Narloch *et al.*, 2013). Another issue raised by the business respondents is whether it is fair for beneficiaries to pay as opposed to 'polluters': 30% stated that *only* environmentally-damaging businesses should have to pay, whilst an additional 30% suggested it would be 'fair' if polluting businesses paid *more* than other contributors. Waylen and Martin-Ortega (2018) reveal that UK environment professionals have voiced concern that PES should not reverse the polluter-pays principle, but should be in addition to this. There is also a question as to whether it is fair for citizens and businesses to be asked to pay for provision of a public good such as urban forest ES at all, given that they are already paying council tax and business rates (Gómez-Baggethun and Muradian, 2015) – a point raised by several of the tree officers and business respondents. This relates to a question raised by Sattler *et al.* (2013) of whether public land should be eligible for PES, given that it is the duty of governments to provide and safeguard public goods.

6.6 Conclusions and recommendations

In response to the continued failure of institutions to enhance provision of urban ES through proactive decision-making, this thesis has contributed important academic knowledge regarding the strong willingness of businesses and citizens to contribute financially to urban ES by means of a public-private urban forest PES scheme. Despite the possible response bias (associated with low response rates, and small and/or unrepresentative samples of respondents), the research conducted for Objectives 2 and 3 nevertheless found over 90% of the business and citizen respondents to be in support of such a scheme. Awareness of the benefits that trees provide to society was high, and there was a sense of moral duty amongst many respondents for improving the quality of their local environment – particularly in terms of air quality which is known to be poor in Southampton.[79] However, it seems prudent to make clear to potential funders (as well as participants in stated preference studies) the realities surrounding ES delivery uncertainty, as it is

[79] Although it should be noted that the effect of tree planting on air quality is small; for instance, London's 8.4 million trees (representing tree canopy cover of 14%) remove only 14% of the air pollutants produced by the city's road traffic (Rogers *et al.*, 2015).

unlikely to dampen their long run support as much as false promises might. Capturing potential funders' subjective beliefs surrounding the likely outcomes of a PES scheme will be important in determining this – both in academic studies and in real schemes. Furthermore, even in the short run (and especially for those who hold individual rather than shared instrumental or relational values), the benefits relating to *being seen* to be doing something virtuous for their local community or city as a whole, may be sufficient for businesses, and perhaps council leaders and citizens, to invest in a public-private urban forest PES scheme.

Based on the findings of this thesis, it is recommended that urban forest PES schemes be piloted by front-running local authorities or third sector intermediaries (ideally supported by national government departments). However, due to the large research gaps identified in Chapter 2, along with the limitations of the second and third papers, it is recommended that such pilots be underpinned by new research, as follows:

- Information is needed on business attitudes towards funding ES, and their expectations regarding the set-up, delivery and outcomes of PES schemes – especially those of smaller businesses.[80]
- Research is required into the practical, operational and legal aspects of developing multi-buyer private sector payment schemes for the provision of multiple-ES in urban environments, as these are likely to be far more complicated than the commonplace single-buyer, single-ES rural schemes.
- The potential role of third sector intermediaries should be investigated in the context of an urban PES scheme. Though intermediaries were not deemed necessary by the business respondents, local authorities are unlikely to have the resources to facilitate such schemes.
- Linked to this, participatory methods involving all stakeholder groups together would be useful to identify further conflicts and issues around setting up a PES partnership, and solutions to these.
- Information is needed on WTP for provision of individual urban forest ES, and whether businesses and citizens would prefer a scheme where ES are bundled, layered, or piggy-backing on one main service.

[80] In a study published in November 2019, Krause and Matzdorf (2019) reveal that 46% of the 26 businesses they interviewed in Germany (the majority being SMEs) would be willing to contribute to a voluntary PES scheme covering a variety of conservation projects nationwide, for reputational and moral reasons. Business investment preferences included: projects in close proximity to company headquarters; flexibility in the timing and size of contributions; and quantification of ES provision – particularly for biodiversity, climate and water-related ES (Krause and Matzdorf, 2019).

- Research is needed to determine whether acknowledging outcome uncertainty improves the realism and credibility of potential PES schemes amongst doubters, and if so, whether this has a positive effect on their WTP.

If the outcomes of this additional research and future pilot schemes are positive, this could be followed by support through national policy, and development of on-the-ground advice and guidance (and perhaps even a specific tool) to enable the future mainstreaming of urban forest PES schemes – and an ES approach to urban planning more generally. Given the key role that businesses and citizens – and potentially intermediaries – will have to play in such schemes, it is important that any guidance or tools are co-produced with input from these stakeholders.

Appendix A Achievements during the PhD candidature

Achievements during the PhD candidature – described in more detail in the following sections – have included:

- publishing three journal articles, two Government reports, two conference papers, an i-Tree report, and two professional magazine articles;
- presenting at 13 conferences – eight in the UK and five elsewhere in Europe;
- undertaking an internship at the National Assembly for Wales (resulting in an additional four publications); and
- demonstrating and lecturing at the University of Southampton.

A.1 Publications

November 2015 – Conference Paper for 3rd European Conference on Biodiversity and Climate Change

The researcher is the lead author of a conference paper presented at the third ECBCC conference, entitled "*Valuing the carbon sequestration and rainwater interception ecosystem services provided by Britain's urban trees*". Proceedings of the European Conference on Nature-based Solutions to Climate Change in Urban Areas and their Rural Surroundings were finally published by the German Federal Agency for Nature Conservation in 2017 (see Davies and Doick, 2017).

September 2016 – Forestry and Woodlands Advisory Committee Report

The researcher is one of five co-authors of a report published on behalf of the Urban Forestry and Woodlands Advisory Committee (FWAC) Network, entitled "*Introducing England's Urban Forests*" (Doick *et al.*, 2016b). The report gives details on England's urban forest resource; as well as available tools for measuring their structure, composition, and provision of ES.

December 2016 – Article in The ARB Magazine

The researcher is the co-author on an article published in the professional magazine of the Arboricultural Association, entitled "*What are urban forests and how beneficial are they?*" (Doick and Davies, 2016). The article explains the research being done to understand, measure and assess the value of urban forests in the UK.

February 2017 – Forestry Commission Research Report

The researcher is the lead author on a Forestry Commission Research Report published by the Forestry Commission on 1st February 2017, entitled "*Delivery of Ecosystem Services by Urban Forests*" (Davies *et al.*, 2017a). The report identifies the key urban forest parameters (relating to scale, structure, location and landuse) that influence the supply of provisioning, regulating and cultural ES and disservices, and discusses the trade-offs and synergies that exist between the supply of these different services.

April 2017 – Conference Paper for Trees People and the Built Environment 3

The researcher is one of seven co-authors of a conference paper presented at Trees People and the Built Environment 3, entitled "*The Canopy Cover of England's Towns and Cities: baselining and setting targets to improve human health and well-being*" (Doick *et al.*, 2017). The paper reveals the canopy cover of 283 towns and cities of England, calculated using the tool i-Tree Canopy. The researcher's role was to investigate the impact of boundary definition (i.e. local authority boundary vs. urban area boundary) on canopy cover assessments.

May 2017 – Article in *Research Ideas and Outcomes*

The researcher was a key contributor to Working Group 4 of an exploratory COST Action project on PES, and is one of 128 co-authors of the resulting article, published by the journal *Research Ideas and Outcomes* (Valatin *et al.*, 2017). Entitled "*PESFOR-W: Improving the design and environmental effectiveness of woodlands for water Payments for Ecosystem Services*", the manuscript aims to help standardize approaches to evaluating the environmental- and cost-effectiveness of woodland-based catchment management projects.

July 2017 – Article in *Environmental Research*: Special Issue on Nature-Based Solutions

The published article (Davies *et al.*, 2017b) makes up Chapter 3 of this thesis. In September 2016, a manuscript addressing Objective 1 of the research (using the data obtained from the interviews with local authority tree officers) was submitted to the editors of the journal *Environmental Research*. Following corrections and resubmission in February 2017, the manuscript, entitled "*Challenges for tree officers to enhance the provision of regulating ecosystem services from urban forests*" was published in July 2017 (within the Special Issue on 'Nature-Based Solutions for Resilient Landscapes and Cities: Innovative Strategies and Scientific Advances').

November 2017 – i-Tree Eco report for Southampton City Council

The researcher was a key contributor to the Southampton i-Tree Eco Study, and one of nine co-authors of the resulting report (Mutch *et al.*, 2017). The study was managed by the University of Southampton (with survey co-ordination and data analysis being carried out by an MEnvSci student), in conjunction with Southampton City Council, Forest Research, and Treeconomics. As with other i-Tree Eco studies, the purpose was to quantify and value the urban forest regulating ES in Southampton, UK.

August 2018 – Article in *Ecosystem Services*

The published article (Davies *et al.*, 2018) makes up Chapter 4 of this thesis. In October 2017, a manuscript addressing Objective 2 of the research (using the data obtained from the interviews with business representatives) was submitted to the editors of the journal *Ecosystem Services*. Following corrections and resubmission in March 2018, the manuscript, entitled "*Business attitudes towards funding ecosystem services provided by urban forests*" was published in August 2018.

June 2019 – Article in The ARB Magazine

The researcher is the sole author of an article published in the professional magazine of the Arboricultural Association, entitled "*Could businesses help fund our urban forests?*". The article explains the results of Objective 2 of the thesis.

A.2 Conferences

18th November 2015 – European Conference on Biodiversity and Climate Change (ECBCC)

Fifteen minute oral presentation at the 3rd ECBCC on 'Nature–Based Solutions to Climate Change in Urban Areas and their rural Surroundings – Linkages between Science, policy and Practice', held in Bonn, Germany. The presentation was entitled "*Valuing the carbon sequestration and rainwater interception ecosystem services provided by Britain's urban trees*" and provided a comparison of results from the first seven large-scale i-Tree Eco surveys carried out in Britain, linking this to climate change resilience and implications for tree planting. This presentation was not based on data collected by the researcher (it was based on data collected and analysed by Forest Research and others during 2010-2014) but is considered relevant to this thesis due to its focus on the value of urban forest regulating ES in Britain.

2nd June 2016 – European Forum on Urban Forestry (EFUF)

Ten minute oral presentation at the 19th EFUF on 'Urban forests for resilient cities', held in Ljubljana, Slovenia. The presentation was entitled "*Essential but under-resourced: are new partnerships required to fund Britain's urban forests?*" and provided a brief overview of the results of the interviews with local authority tree officers (Objective 1).

30th June 2016 – Climate Change: Society, Governance and Economics Conference

Twenty minute oral presentation at an interdisciplinary social science conference for early career researchers on 'Climate Change: Society, Governance and Economics', held in Reading, UK. The presentation was entitled "*Investing in climate adaptation in British cities: Ecosystem services and the urban forest*" and provided an overview of the results of the interviews with local authority tree officers (Objective 1), focusing specifically on urban forest regulating ES and urban forest governance. It also gave an overview of the draft methodology proposed to address Objectives 2 and 3, focusing on the willingness of businesses and citizens to contribute to urban forest ES delivery, as well as the relationship between WTP and spatial datasets on environmental issues and assets.

27th September 2016 – Building Prosperous Cities Conference

Poster presentation at the Ecosystem Knowledge Network's conference on 'The role of natural capital and green infrastructure', held in London, UK. The poster was entitled "*Enhancing provision of urban forest-based regulating ecosystem services in British cities*" and provided a brief overview of the results of the interviews with local authority tree officers (Objective 1), as well as outlines of the other thesis objectives.

4th April 2017 – GreenInUrbs Conference

Ten minute oral presentation at the final GreenInUrbs conference, on 'Nature-based solutions for sustainable and resilient cities', held in Orvieto, Italy. The presentation was entitled "*Is the management of Britain's urban forests really sustainable? Time to take an ecosystem services approach*" and provided an overview of the qualitative results from the interviews with local authority tree officers (Objective 1), along with a summary of the descriptive statistics relating to business attitudes (Objective 2).

20th September 2017 – GREEN SURGE Conference

Fifteen minute oral presentation at the final international GREEN SURGE conference, on 'Urban Green Infrastructure - Connecting People and Nature for Sustainable Cities', held in Malmö,

Sweden. The presentation was entitled "*Could PES schemes fund the regulating ecosystem services provided by urban forests?*" and provided detail on the qualitative and quantitative results from the interviews with business representatives (Objective 2).

13th December 2017 – London Tree Officers Association Seminar

Forty-five minute 'keynote' oral presentation at one of the quarterly seminars of the London Tree Officers Association (LTOA), held in London, UK. Entitled "*Challenges for tree officers to enhance the provision of regulating ecosystem services from urban forests*", the presentation gave detailed results from the local authority tree officer interviews (Objective 1), along with summarised results from the business interviews (Objective 2), and plans for the choice experiments with citizens (Objective 3).

13th November 2018 – Valuing Nature Annual Conference

Fifteen minute oral presentation at the Valuing Nature Annual Conference, held in Cardiff, UK. The presentation was entitled "*Businesses to invest in urban natural capital?*" and again provided detail on the qualitative and quantitative results from the interviews with business representatives (Objective 2).

30th November 2018 – World Forum on Urban Forestry (WFUF)

Fifteen minute oral presentation at the 1st World Forum on Urban Forestry, held in Mantova, Italy. The presentation was entitled "*Future funding of urban forests – time to move to a beneficiary pays model?*" and provided an overview of the results from the choice experiment with Southampton citizens (Objective 3).

7th December 2018 – Forest Research Coffee-break Seminar

Thirty minute oral presentation to colleagues at Forest Research, held in Farnham, UK. The presentation was entitled "*Enhancement of regulating ecosystem services via a new approach to urban forest management, governance and funding in Britain*" and provided an overview of the results of the entire thesis.

31st January 2019 – Ecosystems Knowledge Network Webinar

Thirty minute oral presentation to members of the Ecosystems Knowledge Network via a webinar. The presentation was entitled "*Business attitudes towards funding ecosystem services provided by urban forests*" and again provided detail on the qualitative and quantitative results from the interviews with business representatives (Objective 2).

5th March 2019 – FutureBuild Exhibition

Ten minute oral presentation in the 'Urban Infrastructure Hub' at the FutureBuild exhibition (formerly EcoBuild), held in London, UK. The presentation was entitled "*Engaging communities - how the public value trees*" and again provided an overview of the results from the choice experiment with Southampton citizens (Objective 3), focusing more on the descriptive statistics.

15th March 2019 – Envecon 2019 Conference

Twenty minute oral presentation at the Envecon conference, held in London, UK. The presentation was entitled "*Willingness-to-pay for urban forest-based ecosystem services under conditions of uncertainty*" and again provided an overview of the results from the choice experiment with Southampton citizens (Objective 3), this time focusing on the choice modelling.

20th June 2019 – Evolving the Forest conference

One-hour roundtable discussion at the Evolving the Forest conference, held in Devon, UK. The discussion was entitled "*Tree Urbanistas: The Urban Forest at the heart of 22nd century living*". The researcher was one of four panellists taking part in the discussion, and spoke about the importance of bringing local authorities, businesses and citizens together to build the treed cities of the future.

A.3 Internship

The researcher was awarded an RCUK Policy Internship with the National Assembly for Wales Research Service, based in Cardiff, UK. The internship was undertaken during May to July 2017, within the Clerking team for the Climate Change, Environment and Rural Affairs (CCERA) Committee, with the purpose of supporting the Committee's Inquiry into the Welsh Government's delivery of the 'Woodlands for Wales' strategy.

Outputs of the internship included:

- Contributing to briefings for the CCERA Committee relating to the 'Woodlands for Wales' inquiry, in particular regarding urban trees, the delivery of ES, and the potential for PES schemes.
- Writing an entire briefing (on Brexit-related publications produced by the governments and parliaments in England, Scotland, Wales and Northern Ireland, and how these may be of use to the CCERA Committee), and presenting this directly to the Committee. The researcher was the first intern in the seven year history of internships at the Assembly to present research directly to a Committee.

- Producing three pro-active Research Briefings on environmental topics of relevance to the Assembly. The first – 'Woodland creation in European countries' (Davies, 2017b) – was written in response to an enquiry from one of the members of the CCERA Committee. The second – 'Low Carbon Electricity' (Spragg *et al.*, 2017) – and third briefings – 'The Planning Series: 16 – Habitats Regulations Assessment' (Davies and Dobbs, 2017) – were written on behalf of the National Assembly for Wales Research Service.
- Writing every section (including the Chair's Foreword) of the 'Branching Out' report on the results of the Committee's Inquiry into the Welsh Government's delivery of the 'Woodlands for Wales' strategy (CCERA Committee, 2017). The researcher was the first intern at the Assembly to write a (whole) Committee report.
- Writing a blog article to announce the publication of the 'Branching Out' report on 27th July 2017 (Davies, 2017a).

A.4 Demonstrating

The researcher has completed the following teaching activities for the Centre for Environmental Science at the University of Southampton (module codes in parentheses):

- 5th October 2015 – Supporting staff on undergraduate field trip to Hythe salt marsh (ENVS1006)
- 19th October 2015 – Supporting staff during an Environmental Impact Assessment (EIA) field briefing at Quayside Road (ENVS6028)
- 22nd February 2016 – Supporting staff during an EIA field briefing at Calshot (ENVS2006)
- 25th February 2016 – Supporting staff on undergraduate field trip to The Coppice of Linwood (ENVS1006)
- January to May 2016 – Providing guidance to undergraduate students during eight practical computer sessions using ArcGIS (ENVS2008)
- 18th to 23rd September 2016 – Supporting staff on undergraduate field trip to Swanage (ENVS3011)
- 11th October 2016 – Supporting staff on undergraduate field trip to Hythe salt marsh (ENVS1006)
- 20th October 2016 – Supporting staff during an EIA field briefing at Quayside Road (ENVS6028)
- 9th and 12th December 2016 – Giving two lectures (totalling three hours) on Strategic Environmental Assessment (SEA) (ENVS6028)
- 14th December 2016 – Giving a one hour lecture on Urban Ecosystem Services (ENVS2009)

Appendix A - Achievements

- December 2016 to April 2017 – Providing formative feedback to seven students on a total of 49 scientific reports via group meeting and emails (ENVS1006)
- December 2016 to November 2017 – Unofficially co-supervising a Masters student with her dissertation (ENVS6009)
- 17th March 2017 – Giving a two hour lecture on SEA (ENVS2006)
- 25th September 2017 – Supporting staff on a 'new student' field trip to Marwell Zoo
- 24th October 2017 – Supporting staff during an EIA field briefing at Quayside Road (ENVS6028)
- 28th November 2017 – Giving a two hour lecture on SEA (ENVS6028)
- 19th April 2018 – Giving a one hour lecture on SEA (ENVS2006)
- June to September 2018 – Unofficially co-supervising a Masters student with her dissertation (MATH6001)
- 25th October 2018 – Supporting staff during an EIA field briefing at Quayside Road (ENVS6028)
- 6th December 2018 – Giving a one hour lecture on SEA (ENVS6028)

Appendix B Supplementary material for Paper 1

Data Access Statement: In order to maintain confidentiality of participants, the transcripts from the interviews with local authority tree officers cannot be made openly available.

B.1 Questionnaire for local authorities

Aim: to establish for what objectives the urban forest is funded, governed and managed in Britain, and how this could be improved.

The urban forest

"Urban forests refer to all forest and tree resources in (and close to) urban areas" (Konijnendijk, 2003).

1. How often is the urban forest in your area surveyed? What information is recorded and for what purposes?
2. Do you hold information on trees on private land?
3. Has the size of the urban forest changed in recent years? If so, is the loss/gain in trees mainly associated with public or private land?

Approach to urban forest management

4. What local policies influence management of the urban forest in your area? Are these policies specific to the urban forest or more generic?
5. What are the main objectives for urban forest management in your area?
6. How do you measure whether these objectives have been met?
7. What are the advantages and disadvantages of focusing on these areas?
8. Has this focus changed in recent years, and if so, what was the driver?
9. How does the approach to managing street trees, park trees and woodlands differ?
10. At which geographic scale is the urban forest planned and managed in your area?

Ecosystem services (ES) provided by the urban forest

ES are defined as "the benefits people obtain from ecosystems". They are categorised into provisioning, regulating and cultural services with supporting services underlying these (Millennium Ecosystem Assessment, 2005).

11. Which ES do you think the urban forest in your area is providing?

12. Do you think a change to the urban forest could enhance provision of ES, and if so, how?
13. Which ES are of most concern/interest to the council, businesses and citizens in your area?
14. How is technical/scientific information used to support urban forest planning and management?
15. Would (further) information on the extent and/or value of the ES provided by the urban forest in your area be useful?
16. To what extent does the department/council take an ecosystem services approach to urban forest management, and do you see this being more or less of a focus in future?

Governance of the UF

17. Who are the key decision-makers in governing and managing the urban forest in your area?
18. What is the involvement of volunteers and the third sector?
19. What is the involvement of the private sector?
20. What proportion of urban forest management is contracted out? What tasks do contractors perform and what decisions can they make?
21. To what extent can the various stakeholders get involved in decision-making relating to changes to the UF?
22. What influence does the council have over trees on private land?

Funding of the UF

23. What is the annual budget for urban forest management and maintenance, and on what basis is this calculated?
24. Where does this money come from?
25. How does woodland creation or additional tree planting get funded?
26. Has the source or value of urban forest funding changed in recent years, and if so, what was the driver?
27. Are the funds sufficient to meet planting and maintenance targets over the short and long term?
28. If additional funding was available for the UF, what would you spend it on?
29. Has the council sought any funding from the private sector to support the UF?
30. What are the advantages and disadvantages to the current urban forest funding model?
31. Who do you think should be involved in funding the urban forest in your area?

B.2 Themes and codes for qualitative analysis

Table B.1: Themes and codes for qualitative analysis

Code	Description	No. of TOs	No. of refs
Theme: Addressing health and safety concerns			
Risk, health and safety	Tree officer talks about managing risk, i.e. maintaining trees so they do not pose health and safety risks to people (injury or death) or property/ infrastructure (damage).	15	65
Theme: Complaints about tree disservices			
General complaints	Tree officer refers to the general complaints that stakeholders (particularly citizens and businesses) make about trees.	12	36
Specific disservices	Tree officer mentions the specific disservices of trees that citizens and businesses complain about.	10	16
Influence on management	Tree officer refers to complaints about tree disservices influencing the planning or management of their urban forest. (This code contains quotes from the other two codes in this theme).	8	14
Theme: Reactive approach to urban forest management			
Reactive approach	Tree officer mentions that actions by their tree team are reactive, for example in response to health and safety concerns or complaints about tree disservices.	13	35
Desire to be proactive	Tree officer refers to a desire to move towards more proactive, planned management of the urban forest. (This code contains quotes from the other code in this theme).	9	15
Theme: Current attempts at an ecosystem services approach			
Passive ES approach	Tree officer mentions that ecosystem services are referred to in written documents, or are 'accounted for' in decision making but without giving specific examples.	6	6
Active ES approach	Tree officer refers to specific directed actions that seek to enhance provision of urban forest ES.	3	7
Theme: Understanding of environmental issues			
Air pollution / purification	Tree officer refers to the regulating ES of air purification, and/or recognises the connection between lack of tree cover and the problem of poor air quality in the city.	13	40
Flooding / stormwater attenuation	Tree officer refers to the regulating ES of stormwater attenuation, and/or recognises the connection between lack of tree cover and the problem of surface water flooding in the city.	11	37
Heat islands/ amelioration	Tree officer refers to the regulating ES of heat amelioration, and/or recognises the connection between lack of tree cover and problems of heatwaves and UHI effects in the city.	10	23
Theme: Political support for trees			
Advocates in high places	Tree officer refers to 'political will' of politicians, department heads or budget holders within their council that support urban forest management and/or ecosystem services.	9	18
Adoption of tree strategy	Tree officer mentions having a tree or urban forest strategy either drafted or already adopted.	6	11
General political support	Tree officer refers to some level of support for trees and/or ecosystem services amongst politicians in general, or their own council showing an interest in being green, resilient or sustainable.	7	9
Supportive planning policy	Tree officer refers to planning policies that support the urban forest and/or consideration of ecosystem services in development planning.	5	6

Code	Description	No. of TOs	No. of refs
Theme: Constraints to undertaking an ecosystem services approach			
Funding constraints	Tree officer refers to not having enough money to enhance ecosystem services (or even carry out necessary tree works), and/or experience of budget reductions.	10	36
Unsupportive governance structures	Tree officer mentions lack of support for ecosystem services or the urban forest from councillors or other local authority departments, or refers to decision-making about trees being taken out of their hands.	9	21
People not taking trees seriously	Tree officer refers to trees (or ecosystem services) not being considered seriously by other council departments (e.g. planning, highways), politicians, citizens or businesses.	11	20
Limited understanding of ecosystem services amongst stakeholders	Tree officer refers to a lack of knowledge or understanding about ecosystem services amongst citizens, business or the council, or the need to educate others about the benefits of trees.	11	17
Theme: Promoting an ecosystem services approach			
Awareness raising	Tree officer refers to the need to promote the benefits of trees to citizens, businesses, politicians or other stakeholders, for example by quantifying or valuing the ecosystem services they provide.	13	31
Novel funding streams	Tree officer refers to the need for citizens or businesses or other beneficiaries/polluters to contribute financially (or in-kind) to the urban forest or ecosystem services.	11	23
Strategic planning	Tree officer refers to the importance of having a tree or urban forest strategy in place (or some other form of strategic plan) to facilitate taking an ecosystems approach.	9	22

B.3 Descriptive statistics for study cities

Geographic, population and tree-related data (including geographic location, geographic size, population size, population density, adoption of a tree strategy, tree canopy cover, and tree budget per head of population) were obtained for each of the study cities. In order to protect the identity of the study cities, numerical data (such as for population size) has been transformed into size classes.

The five themes used for classifying local authority tree officer responses for this analysis are as follows:

1. Proactive approach to urban forest management, vs. reactive approach.
2. Regulating ecosystem services influence management vs. not considered in management.
3. Issues with air pollution, flooding (and urban heat island) vs. no reported issues.
4. Constraints to adopting an ecosystem services approach vs. no reported constraints.
5. Opportunities for promoting an ecosystem services approach vs. no suggested opportunities.

These are based on the themes used for the qualitative analysis (shown in Table B.1). Tree officers have been grouped according to the frequency with which they raised certain themes, and what they said on the subject. The results from this analysis are shown in Table B.2.

Table B.2: City statistics linked with local authority tree officer responses

Sub-theme	Tree officer	Area (ha)	Population	Population density	Tree strategy status	Tree canopy cover (%)	Tree budget / head (£)
Mean for all 15 cities		9,931	373,030	39.3	0.37	14.8	1.92
Theme 1: Proactive approach to urban forest management, vs. reactive approach							
Proactive approach	TO4	5-10,000	250-350,000	35-45	1	10-15	1.50-1.75
	TO12	5-10,000	250-350,000	30-35	0.5	10-15	<1.50
	TO13	10-15,000	350-450,000	<30	0.5	>20	<1.50
	Mean	10,454	335,330	33.8	0.67	15.9	1.41
Reactive approach (focused on risk and complaints)	TO1	<5,000	<250,000	>45	0	>20	1.75-2.00
	TO2	10-15,000	250-350,000	<30	0.5	10-15	n/a
	TO6	<5,000	<250,000	>45	0.5	10-15	<1.50
	TO7	5-10,000	250-350,000	30-35	0.5	15-20	<1.50

[81] Tree strategy status has been defined as follows: Published within the last 5 years = 1; Published more than 10 years ago = 0.5; Currently being drafted = 0.5; Neither published nor in draft = 0.

[82] Tree canopy cover data has been obtained by the authors using the software package i-Tree Canopy.

[83] Tree budgets are for the 2015-2016 financial year, and in many (but not all) cases, estimated revenue from external sources (e.g. grants and business sponsorship) has been included.

Sub-theme	Tree officer	Area (ha)	Population	Population density	Tree strategy status	Tree canopy cover (%)	Tree budget / head (£)
	TO8	<5,000	<250,000	>45	0	<10	1.75-2.00
	TO10	>15,000	>450,000	30-35	0	10-15	1.50-1.75
	TO11	10-15,000	>450,000	35-45	0	10-15	<1.50
	TO15	>15,000	>450,000	35-45	0.5	15-20	>2.00
	Mean	11,015	423,850	40.7	0.25	14.5	1.70
Theme 2: Regulating ecosystem services influence management vs. not considered in management							
Regulating ES influence management	TO5	10-15,000	350-450,000	35-45	0	15-20	>2.00
	TO10	>15,000	>450,000	30-35	0	10-15	1.50-1.75
	TO15	>15,000	>450,000	35-45	0.5	15-20	>2.00
	Mean	18,403	714,495	38.6	0.17	16.5	2.23
Regulating ES not considered in management	TO2	10-15,000	250-350,000	<30	0.5	10-15	n/a
	TO6	<5,000	<250,000	>45	0.5	10-15	<1.50
	TO8	<5,000	<250,000	>45	0	<10	1.75-2.00
	TO11	10-15,000	>450,000	35-45	0	10-15	<1.50
	TO12	5-10,000	250-350,000	30-35	0.5	10-15	<1.50
	TO14	5-10,000	250-350,000	35-45	0.5	<10	1.75-2.00
	Mean	7,986	296,349	39.8	0.33	10.9	1.49
Theme 3: Issues with air pollution, flooding (and urban heat island) vs. no reported issues							
Issues with air pollution, flooding (and urban heat island)	TO1	<5,000	<250,000	>45	0	>20	1.75-2.00
	TO5	10-15,000	350-450,000	35-45	0	15-20	>2.00
	TO7	5-10,000	250-350,000	30-35	0.5	15-20	<1.50
	TO8	<5,000	<250,000	>45	0	<10	1.75-2.00
	TO9	<5,000	<250,000	35-45	1	15-20	1.50-1.75
	TO10	>15,000	>450,000	30-35	0	10-15	1.50-1.75
	TO13	10-15,000	350-450,000	<30	0.5	>20	<1.50
	TO15	>15,000	>450,000	35-45	0.5	15-20	>2.00
	Mean	11,287	421,816	39.3	0.31	17.2	1.84
No reported environmental issues	TO3	5-10,000	250-350,000	>45	0	10-15	>2.00
	TO4	5-10,000	250-350,000	35-45	1	10-15	1.50-1.75
	TO12	5-10,000	250-350,000	30-35	0.5	10-15	<1.50
	TO14	5-10,000	250-350,000	35-45	0.5	<10	1.75-2.00
	Mean	7,950	311,765	39.6	0.5	12.4	2.46
Theme 4: Constraints to adopting an ecosystem services approach vs. no reported constraints							
Many reported constraints	TO1	<5,000	<250,000	>45	0	>20	1.75-2.00
	TO2	10-15,000	250-350,000	<30	0.5	10-15	n/a
	TO13	10-15,000	350-450,000	<30	0.5	>20	<1.50
	Mean	10,124	296,473	33.3	0.33	18.1	1.62
Few/no reported constraints	TO9	<5,000	<250,000	35-45	1	15-20	1.50-1.75
	TO10	>15,000	>450,000	30-35	0	10-15	1.50-1.75
	TO14	5-10,000	250-350,000	35-45	0.5	<10	1.75-2.00
	TO15	>15,000	>450,000	35-45	0.5	15-20	>2.00
	Mean	13,858	529,886	37.8	0.5	15.0	2.05

Sub-theme	Tree officer	Area (ha)	Population	Population density	Tree strategy status	Tree canopy cover (%)	Tree budget / head (£)
Theme 5: Opportunities for promoting an ecosystem services approach vs. no suggested opportunities							
Many suggested opportunities	TO5	10-15,000	350-450,000	35-45	0	15-20	>2.00
	TO6	<5,000	<250,000	>45	0.5	10-15	<1.50
	TO7	5-10,000	250-350,000	30-35	0.5	15-20	<1.50
	TO15	>15,000	>450,000	35-45	0.5	15-20	>2.00
	Mean	12,515	504,086	40.8	0.38	16.6	1.89
No suggested opportunities	TO3	5-10,000	250-350,000	>45	0	10-15	>2.00
	TO4	5-10,000	250-350,000	35-45	1	10-15	1.50-1.75
	TO9	<5,000	<250,000	35-45	1	15-20	1.50-1.75
	TO13	10-15,000	350-450,000	<30	0.5	>20	<1.50
	TO14	5-10,000	250-350,000	35-45	1	<10	1.75-2.00
	Mean	8,003	284,950	37.9	0.6	15.3	2.35

Appendix C Supplementary material for Paper 2

Data Access Statement: In order to maintain confidentiality of participants, the transcripts from the interviews with businesses cannot be made openly available. However, the raw statistical data from the interviews is openly available from the University of Southampton repository: https://doi.org/10.5258/SOTON/D1207

C.1 Interview guide for businesses

Purpose of the interview:

- To find out the extent to which businesses in Southampton value urban trees and the natural environment.
- To find out whether businesses support the idea of an environment partnership between the public and private sectors for funding urban trees.
- To find out the conditions under which businesses would be willing to contribute financially to Southampton's urban trees.

The reasons for your answers to the following (yes/no) questions will be explored during the interview. You do not need to answer any of these questions in advance.

Costs and benefits of urban trees

1. Urban trees can pose a nuisance to businesses. How relevant/important are these tree nuisances to your organisation?

Tree nuisances	Not relevant	Quite relevant	Very relevant	Don't know
Leaves or fruit falling onto business premises	☐	☐	☐	☐
Bird excrement and/or tree sap falling onto vehicles	☐	☐	☐	☐
Branches or trees falling onto property or vehicles	☐	☐	☐	☐
Structural damage from tree roots (e.g. building subsidence or uneven paths)	☐	☐	☐	☐
Pollen from trees aggravating staff allergies (hay fever)	☐	☐	☐	☐
Trees blocking sunlight	☐	☐	☐	☐
Trees blocking views	☐	☐	☐	☐
Trees reducing visibility of business signs or entrances	☐	☐	☐	☐
Dark shadows from dense foliage causing fear	☐	☐	☐	☐
Other – please specify:	☐	☐	☐	☐

2. Does your organisation currently incur any expenditure associated with these nuisances (or do you actually make a business out of this)?

Yes ☐ No ☐

3. Urban trees can also provide a range of benefits to businesses. How relevant/important are these tree benefits to your organisation?

Tree benefits	Not relevant	Quite relevant	Very relevant	Don't know
Reduced carbon dioxide (greenhouse gas) levels	☐	☐	☐	☐
Reduced local flood risk	☐	☐	☐	☐
Reduced impact from excessive summer heat	☐	☐	☐	☐
Improved local air quality	☐	☐	☐	☐
Reduced city noise levels	☐	☐	☐	☐
Improved physical and mental health of employees	☐	☐	☐	☐
Improved appearance / beauty / character of local area	☐	☐	☐	☐
Attraction of customers / investors / employees	☐	☐	☐	☐
Provision of habitat for city wildlife	☐	☐	☐	☐
Other – please specify:	☐	☐	☐	☐

4. Does your organisation currently experience any cost savings or additional revenue that could be attributed to the benefits that trees provide?

Yes ☐ No ☐

Relationship between business and the natural environment

5. Has your organisation been affected by extreme weather conditions, for example flooding or excessive summer heat?

Yes ☐ No ☐

6. Do you have any concerns about the possible impact of future climate change on your organisation?

Yes ☐ No ☐

7. Does your organisation seek to limit its adverse effects on the natural environment (e.g. through recycling, low emission vehicles, etc.)?

Yes ☐ No ☐

8. Does your organisation seek to enhance its beneficial effects on the natural environment (e.g. through corporate social responsibility)?

Yes ☐ No ☐

Public-private funding for urban trees

9. Local councils have limited funds to spend on tree planting and maintenance, and so they are looking to the private sector for support. Do you agree with the principle of the private sector contributing to urban trees?

Yes ☐ No ☐

10. Do you think that a partnership between the public and private sectors (perhaps also involving charities) could be made to work for funding urban trees (e.g. as it does for the beautification of roundabouts)?

Yes ☐ No ☐

11. Who do you think should contribute to financing the planting and maintenance of Southampton's urban trees? Tick all that apply.

Central government	☐	Businesses (all)	☐
The local council	☐	Businesses (those causing pollution)	☐
Charities	☐	Businesses (those causing loss of trees)	☐
Citizens	☐	Other – please specify:	☐

12. What would be your organisation's motivations for contributing to Southampton's urban trees? Tick all that apply.

It will increase our profitability, e.g. through higher sales	☐
It will improve the health and wellbeing of our employees	☐
It will enhance our reputation as a green and sustainable business	☐
It supports the aims of our corporate (social responsibility) strategy	☐

It will help reduce our exposure to the impacts of climate change	☐
It pre-empts any taxes the council may otherwise ask for	☐
It is our moral duty	☐
Other – please specify:	☐

13. How much involvement would your organisation like in decisions regarding tree planting and maintenance activities in Southampton?

None	☐
We wish to be informed about the decisions made by the council	☐
We wish to contribute to decision making by responding to consultations	☐
We wish to make the decisions as part of a steering group	☐

Arranging the financial transaction

14. If businesses in Southampton were to contribute to the city's urban trees, do you think this should be:

Voluntary?	☐
Mandatory?	☐

15. If contributing voluntarily, would your organisation prefer:

A set annual payment?	☐
A completely open contribution amount?	☐
To select from a list of costed projects to fund directly?	☐

16. Would you wish your organisation's voluntary contribution to be publicised?

Yes ☐ No ☐

17. If business contributions became mandatory in Southampton, would your organisation prefer:

A blanket rate payable by all businesses?	☐
Different rates for micro, small, medium and large enterprises?	☐
A variable rate linked to the impact the business has on the environment?	☐
Don't know?	☐

Conditions of involvement in a public-private funding scheme

18. Would your organisation prefer to contribute financially to:

The city's trees as a whole?	☐
Only trees in the immediate vicinity of your business premises?	☐

19. Which of these would your organisation be interested in contributing to? Tick all that apply.

Enhanced maintenance of existing trees?	☐
Replanting in areas that already have (some) trees?	☐
Planting in areas currently devoid of trees?	☐

20. Which tree benefits and nuisances would you prefer the council to focus on? Tick all that apply.

Tree nuisances		Tree benefits	
Leaf / fruit fall	☐	Reducing greenhouse gas levels	☐
Bird excrement / tree sap	☐	Reducing local flood risk	☐
Branch / tree fall	☐	Reducing impact of excessive heat	☐
Damage from tree roots	☐	Improving local air quality	☐
Allergies from pollen	☐	Reducing city noise levels	☐
Trees blocking sunlight	☐	Improving citizen / employee health	☐
Trees blocking views	☐	Improving appearance of local area	☐
Trees blocking signs / entrances	☐	Attracting customers / investors	☐
Shadows from dense foliage	☐	Providing habitat for wildlife	☐
Other – please specify:			☐

21. Given that trees need to grow and mature to deliver benefits to their fullest potential, would the delay in the delivery of tree benefits affect the willingness of your organisation to contribute financially?

Yes ☐ No ☐

22. Would your organisation require planting/maintenance activities (or even delivery of tree benefits) to be monitored (e.g. by a charity or regulator) to justify the financial contribution?

Yes ☐ No ☐

23. Would the willingness of your organisation to take part depend on the cost-effectiveness of the tree planting and maintenance programme?

Yes ☐ No ☐

24. Would you be more willing to participate if you were presented first with:

An environmental case for urban trees?	☐
A business case for urban trees?	☐
Other – please specify:	☐

About your business

25. What is your organisation's main line of work?

26. Is your organisation classed by Companies House as:

Micro (≤ 10 employees, turnover ≤ £632,000)?	☐
Small (11-50 employees, turnover ≤ £6.5 million)?	☐
Medium (51-250 employees, turnover ≤ £25.9 million)?	☐
Large (> 250 employees, turnover > £25.9 million)?	☐

C.2 Summary of qualitative results

Table C.1: Themes and codes for qualitative analysis

Code	Description	No. of BRs	No. of refs
RQ1. What are business attitudes towards trees and the ES they provide?			
Theme: Tree cover in vicinity of business premises (13 Sources; 15 Refs)			
Concrete jungle	BR refers to the absence of trees and/or prevalence of concrete within and around their business premises	11	13
Green area	BR mentions being located in a leafy area	2	2
Theme: Positive attitude towards trees and/or the ES they provide (26 Sources; 79 Refs)			
Provisioning ES	BR mentions the beneficial provision of goods (e.g. fruit) from urban trees	2	2
Regulating ES	BR mentions the nature-based solutions that trees provide to mitigate environmental issues (e.g. heat, flood and air quality regulation)	14	32
Cultural ES	BR mentions the benefits that trees provide to people (e.g. aesthetic beauty and improved mental health)	16	26
General tree benefits	BR mentions that trees are beneficial, but doesn't specify how	13	15
Financial tree benefits	BR suggests that trees can have financial benefits for businesses	6	8
No Disservices	BR does not consider trees to be a nuisance	7	7
Theme: Negative attitude towards trees and/or the ES they provide (16 Sources; 26 Refs)			
Don't care about trees	BR admits that their business and/or their customers/employees have no interest in trees	8	9
Trees cause a nuisance	BR complains about tree disservices affecting their business	7	12
UF-based ES are not important	BR states that certain ES (e.g. heat amelioration) from Southampton's trees are irrelevant to their business	5	6
Theme: Concerned about the environment and/or the effects of climate change (27 Sources; 64 Refs)			
Air pollution issues	BR mentions that their premises, business or the city has (or is likely to have) problems with air pollution	10	16
Flooding issues	BR mentions that their premises, business or the city has (or is likely to have) problems with flooding	13	23
Heat issues	BR mentions that their premises, business or the city has (or is likely to have) problems with heat	9	14
Other climate issues	BR mentions other environmental/climate concerns the business has (e.g. sea level rise)	16	18
Theme: Proactive sustainability and CSR activities (20 Sources; 32 Refs)			
Natural env't focus	BR mentions what they do to enhance the natural environment	11	13
Social focus	BR mentions what they do to benefit people/ communities	6	7
Sustainability focus	BR mentions what they do to enhance wider sustainability	10	12
RQ2. What are business attitudes towards private sector investment in urban forests?			
Theme: Wary of private sector contributions to urban trees (27 Sources; 104 Refs)			
Public sector responsibility	BR believes urban trees to be the council's responsibility; businesses should not be forced to get involved	6	6
	Citizens already pay tax; they shouldn't be expected to contribute more	6	9
Only polluters should pay	BR thinks only businesses causing pollution or loss of trees should contribute	7	14

Code	Description	No. of BRs	No. of refs
Voluntary contribution only	BR explains why contributions from businesses should be on a voluntary (rather than mandatory) basis	24	33
In-kind contribution welcome	BR would volunteer their time, staff or equipment, but not money	2	2
	BR suggests that in-kind contributions may be more popular with businesses and citizens	3	3
Need tangible or financial business benefit	BR would require a tangible/financial business benefit, and/or trees to be planted in their immediate vicinity to get their support	19	35
Theme: Positive attitude towards an urban forest PES scheme (28 Sources; 123 Refs)			
All businesses should pay	BR explains why contributions from businesses should be on a mandatory (rather than voluntary) basis	14	19
Moral duty	BR says that investing in trees is a moral duty for businesses and society in general	14	24
Polluters should pay more	BR thinks polluters or those causing loss of trees should contribute more than other businesses to right the wrong they have caused	10	13
Good for publicity and buy-in	BR says they would use their involvement in the tree programme to promote their business and/or help with staff engagement	17	35
Win-win	BR suggests they'd be keen to do something that benefits society, as long as the business also benefits	9	10
Societal benefit sufficient	BR suggests that they would invest in trees for societal benefit (rather than business benefit)	16	24
Seek to encourage others	BR suggests that they would try to encourage other businesses to contribute to the tree programme	5	7
RQ3. What are business preferences regarding the operation of an urban forest PES scheme?			
Theme: Partnership working between the council, businesses and citizens (19 Sources; 38 Refs)			
Business-Council partnership	BR suggests (how) businesses could work together with the council	15	20
Citizen contribution	BR suggests that citizens should play their part, either financially or through volunteering	8	9
Need for a steering group	BR would expect a steering group to make the decisions (rather than the council alone), and/or wishes to be on the steering group in order to influence those decisions	9	11
Theme: Information provision before and during the implementation of the PES scheme (30 Sources; 85 Refs)			
Making the case to invest	BR suggests that the council provides certain information (phrased or displayed in a specific way) to persuade businesses to invest	14	16
Upfront project transparency	BR says the business would need to know exactly where and on what the council would spend their money (i.e. precise project details) before agreeing to invest	11	14
Trust Council to implement	BR trusts that the council will manage the scheme appropriately, and so doesn't require information on scheme delivery	13	18
Planting and maintenance record	BR requires ongoing evidence of planting and maintenance activities because they don't trust the council to do it properly	12	15
Cost-effectiveness of scheme	BR says the cost-effectiveness of the tree programme would influence their (continued) involvement	20	23
Delivery of ES benefits	BR suggests that the tree programme should be monitored to make sure that it is delivering the stated benefits	8	9
Theme: Recommendations for a fair and smooth running scheme (24 Sources; 52 Refs)			
Simplicity is key	BR suggests that the scheme should be as simple as possible to avoid wasting money on complex or controversial calculations and decisions	11	18
Fair for all business sizes	BR mentions that businesses of a certain size will be impacted differently by (proposed elements of) the tree programme	12	13

Code	Description	No. of BRs	No. of refs
Locate trees by need	BR mentions that trees should be planted in areas of need and/or where they are best suited, to avoid benefitting only the richer areas	8	11
Other ideas for scheme	BR suggests a personal idea about how the scheme might be designed or managed	13	16

C.3 Summary of quantitative results

Table C.2: Variables for quantitative analysis

Input variable[a]	Outcome variable[a]	Df[b]	Critical value	χ^2 value	P value	Interpretation[c]
RQ1. What are business attitudes towards trees and the ES they provide?						
Incurs expenditure associated with tree nuisances (Q2)	Leaves falling onto premises quite or very relevant (Q1)	1	3.841	4.836	0.028 **	Leaf fall is more likely to be considered a nuisance by firms that incur tree-related expenditure than those that do not
Located in an area with at least a moderate probability of surface water flooding	Concerned about impact of future climate change on the business (Q6)	1	3.841	4.464	0.035 **	BRs whose premises are located in an area with a flooding issue are more likely to be concerned by future climate change than those which are not in such areas
Firm is medium or large in size (Q26)	Wants active involvement in urban tree decision-making (Q13)	1	3.841	3.229	0.072 *	Active involvement (i.e. steering group or responding to consultations) is preferred by BRs from medium-large firms, whilst minimal involvement (i.e. none or being informed about decisions made) is preferred by those from micro-small firms
Firm is medium or large in size (Q26)	Concerned about impact of future climate change on the business (Q6)	1	3.841	2.829	0.093 *	Future climate change is more likely to be a concern to BRs from medium-large firms than to those from micro-small firms
RQ2. What are business attitudes towards private sector investment in urban forests?						
Motivated to contribute by a desire to improve employee health and wellbeing (Q12)	Willing to contribute to enhanced maintenance of existing trees (Q19)	1	3.841	5.111	0.024 **	Enhanced maintenance of existing trees (as opposed to just planting new trees) is more likely to be of interest to BRs motivated to contribute by a desire to improve employee health and wellbeing
Has been affected by extreme weather events (Q5)	Motivated to contribute by a desire to support aims of CSR strategy (Q12)	1	3.841	3.601	0.058 *	BRs whose organisations have been affected by flooding or excessive summer heat are more likely to be motivated to contribute for CSR reasons (i.e. to support social and environmental concerns in their business operations) than those that have not been affected by such events
Firm is medium or large in size (Q26)	Motivated to contribute by a desire to support aims of CSR strategy (Q12)	1	3.841	3.416	0.065 *	BRs from medium-large firms are more likely to be motivated to contribute for CSR reasons than are those from micro-small firms
Located in an area with at least a moderate probability of surface water flooding	Motivated to contribute by a desire to reduce exposure to climate change impacts (Q12)	1	3.841	2.917	0.088 *	BRs whose premises are located in an area with a flooding issue are more likely to be motivated to contribute by a desire to reduce their exposure to climate change impacts than those that are not in such areas

Input variable[a]	Outcome variable[a]	Df[b]	Critical value	χ^2 value	P value	Interpretation[c]
RQ3. What are business preferences regarding the operation of an urban forest PES scheme?						
Thinks business contributions should be mandatory as opposed to voluntary (Q14)	Voluntary options of a) set annual payment; b) open contribution; c) fund projects directly (Q15)[d]	2	5.991	11.045	0.004 ***	BRs preferring voluntary contributions are more likely to want to fund specific projects directly; those preferring mandatory payments are more likely to want set annual payments
Concerned about impact of future climate change on the business (Q6)	Would wish funds raised from businesses to be spent on reducing impact of excessive summer heat (Q20)	1	3.841	4.904	0.027 **	BRs concerned by future climate change are more likely to want the money spent on reducing the impact of excessive summer heat than those without such concerns
Motivated to contribute by a desire to improve employee health and wellbeing (Q12)	Would be more willing to contribute if presented with an environmental case (Q24)	1	3.841	3.308	0.069 *	BRs motivated to contribute by a desire to improve employee health and wellbeing are more likely to want to see an environmental case for urban trees than those without such motivations

* significant at 10% level; ** significant at 5% level; *** significant at 1% level

[a] Variables taken from questionnaire include question number in parentheses

[b] Continuity correction applied where degrees of freedom = 1

[c] Due to the exploratory nature of the study, corrections for multiple tests where the same input variables have been used (to avoid Type I errors) have not been undertaken. These results should therefore be interpreted with caution.

[d] This variable is categorical; all other variables are binary

Appendix D Supplementary material for Paper 3

Data Access Statement: The raw statistical data from the questionnaire-based choice experiment is openly available from the University of Southampton repository: https://doi.org/10.5258/SOTON/D1207

D.1 Questionnaire for citizens (uncertain version)

Street trees in Southampton

1. A street tree is a tree located on public land next to a road (e.g. on a pavement or grass verge). Does the road you live on have any street trees?

   ☐ Yes
   ☐ No
   ☐ Don't know

2. Street trees can pose a nuisance to pedestrians, drivers, residents, and society in general. Please read the following statements and indicate how important these tree nuisances are for you:

		Very important	Quite important	Slightly important	Not at all important	Don't know
a)	Leaves or fruit falling onto pavements, parked cars or into gardens	☐	☐	☐	☐	☐
b)	Bird poo or tree sap falling onto parked cars	☐	☐	☐	☐	☐
c)	Damage to pavements from tree roots	☐	☐	☐	☐	☐
d)	Pollen from trees aggravating allergies (hay fever)	☐	☐	☐	☐	☐
e)	Trees blocking sunlight	☐	☐	☐	☐	☐
f)	Trees blocking TV signal	☐	☐	☐	☐	☐

3. Street trees can also provide benefits to pedestrians, drivers, residents, and society in general. Please read the following statements and indicate how important these tree benefits are for you:

		Very important	Quite important	Slightly important	Not at all important	Don't know
a)	Trees reducing risk of flooding	☐	☐	☐	☐	☐
b)	Trees providing shade in hot weather	☐	☐	☐	☐	☐
c)	Trees improving local air quality	☐	☐	☐	☐	☐
d)	Trees improving people's mental health/wellbeing	☐	☐	☐	☐	☐

		Very important	Quite important	Slightly important	Not at all important	Don't know
e)	Trees improving the attractiveness of a place	☐	☐	☐	☐	☐
f)	Trees increasing property value	☐	☐	☐	☐	☐
g)	Trees providing habitat for city wildlife	☐	☐	☐	☐	☐

Environmental problems and solutions

Air pollution

Air pollution is a serious problem in Southampton, and exceeds safety limits set by the UK Government. It can cause a wide range of health problems, including stroke, heart disease, lung cancer and asthma. Records from Public Health England show that air pollution causes around 115 people to die prematurely every year in Southampton.

Some people are more at risk of ill-health from air pollution than others. High risk groups include:

- people with existing cardiovascular (heart) and respiratory (lung) conditions;
- people who live in deprived or low-income areas;
- people who live in areas with high vehicular traffic (particularly lorries or queueing vehicles).

Addressing air pollution

Road transport is the biggest contributor to air pollution in Southampton. To help prevent such pollution, the council is implementing a 'Clean Air Zone' to discourage the most polluting vehicles from entering the city.

Another way of improving air quality along the city's roads is to plant new street trees. Trees remove pollutants from the air by absorbing them through their branches, trunks, and particularly through their leaves.

4. Please read the following statements and indicate to what extent you agree with each statement

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Don't know
a)	I am concerned about air pollution in Southampton	☐	☐	☐	☐	☐	☐
b)	I think measures to prevent air pollutants (e.g. discouraging vehicle use) are a good idea	☐	☐	☐	☐	☐	☐
c)	I think measures to remove air pollutants (e.g. planting trees) are a good idea	☐	☐	☐	☐	☐	☐

5. On a scale of 0 (not at all confident) to 10 (very confident), how confident are you that planting new trees on Southampton's streets would reduce air pollution in the city?

Not at all confident	0	1	2	3	4	5	6	7	8	9	10	Very confident
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Flooding

When rainfall is particularly intense or prolonged, the city's drainage network may be overwhelmed, causing localised surface water flooding. This is particularly common in urban areas because man-made surfaces such as asphalt, tarmac and brick stop the rain from being absorbed into the soil. Environment Agency data shows that around 10,000 properties are at risk of surface water flooding in Southampton.

This type of flooding can happen anywhere in the city, but certain locations are more at risk than others. High risk locations include:

- low lying areas (e.g. dips in roads, at bottoms of hills, or near sea-level);
- areas with lots of man-made surfaces, and little vegetation.

Addressing flooding

To help prevent flooding, the council is working to improve the drainage network across the city. They also require sustainable drainage to be used on new development sites to minimise surface water run-off.

Another way of reducing surface water flooding in the city is to plant new street trees. Trees help rainfall to penetrate into the soil via their trunks. They also store rainfall on their leaves (which later evaporates), and take up water through their roots.

6. Please read the following statements and indicate to what extent you agree with each statement

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Don't know
a)	I am concerned about surface water flooding in Southampton	☐	☐	☐	☐	☐	☐
b)	I think measures to prevent flooding (e.g. improving the drainage network) are a good idea	☐	☐	☐	☐	☐	☐
c)	I think measures to reduce flooding (e.g. planting trees) are a good idea	☐	☐	☐	☐	☐	☐

7. On a scale of 0 (not at all confident) to 10 (very confident), how confident are you that planting new trees on Southampton's streets would reduce surface water flooding in the city?

Not at all confident	0	1	2	3	4	5	6	7	8	9	10	Very confident
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Predicting future benefits

Engineers and scientists can quite accurately calculate the benefits of upgrading the drainage network or removing highly polluting vehicles from the city. However, calculating the effects of new tree planting on air quality and flooding is much more difficult. This is because tree benefits are affected by:

- the type (species), size, health, and maintenance of the trees;
- how close the trees are located to buildings, people, pollution sources, and other trees.

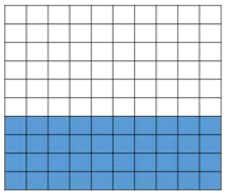
Therefore, we often communicate tree benefits as probabilities. We often hear about probabilities during daily weather forecasts. For example, if the weather forecast is "an 80% chance of rain", this means that:

- 80 times out of 100 it will rain;
- 20 times out of 100 it will stay dry.

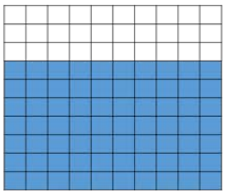
If the forecast is "a 100% chance of rain", then it is certain to rain.

8. Which of the following three cities is <u>least</u> likely to rain tomorrow?

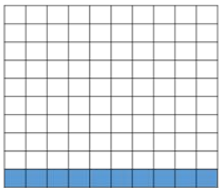
City A
40% chance of rain tomorrow



City B
70% chance of rain tomorrow



City C
10% chance of rain tomorrow



☐ City A
☐ City B
☐ City C
☐ Don't know
[If wrong answer selected, the correct answer (with explanation) will pop up]

Proposed tree planting programme

Because of the problems with air pollution and surface water flooding, the council would like to plant more street trees. However, the council only has funds available for the maintenance and

replacement of *existing* trees. To enable the council to go ahead with this tree planting programme, extra funding is needed.

It has been proposed that the additional money be raised through the creation of a City Tree Fund, payable by **all** council tax payers. The purpose of this survey is to collect Southampton residents' views on such a programme, and their willingness to support it.

In the next section you will be asked to make 12 choices from a set of possible tree programmes. Your choices will tell us how much you, as a resident of Southampton, might be willing to pay for new tree planting in the city's streets. You can also use this survey to tell the council you are not interested in paying for new street trees, by choosing the '*no* tree programme' option.

First, here are 5 important factors for you to consider in your choices:

1) **Trees can reduce the number of pollution-related deaths**

   Air pollution causes around 115 people to die prematurely each year in Southampton. More trees can help to reduce the number of pollution-related deaths.

   In the tree programme choices that follow, 'yearly reduction in pollution-related deaths' might take one of four levels:

   - No reduction (115 pollution-related deaths)
   - 1 fewer pollution-related deaths
   - 4 fewer pollution-related deaths
   - 7 fewer pollution-related deaths

2) **Trees can reduce the number of residential properties at risk of flooding**

   Surface water run-off from extreme rainfall puts around 10,000 residential properties at risk of flooding in Southampton. More trees can help to reduce this flood risk.

   In the tree programme choices that follow, 'reduction in residential flood risk' might take one of four levels:

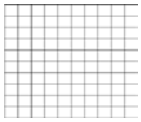
   - No reduction (10,000 residential properties at risk of flooding)
   - 100 fewer residential properties at risk of flooding
   - 300 fewer residential properties at risk of flooding
   - 500 fewer residential properties at risk of flooding

3) **The health and flood benefits of new trees are difficult to predict**

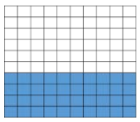
   The benefits of new tree planting will vary depending on the type (species), size, health, and maintenance of the trees. The benefits will also depend on how close the trees are

located to buildings, people, pollution sources, and other trees. These are difficult to calculate and predict. Because of this, there is a chance that the predicted health and flood benefits might not happen.

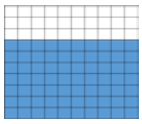
In the tree programme choices that follow, the 'likelihood that reductions in pollution-related deaths and residential flood risk will occur' might take one of four levels:



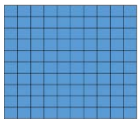
0% (no tree programme means no reductions)



40% chance of reductions in deaths and flood risk occurring



70% chance of reductions in deaths and flood risk occurring



100% chance of reductions in deaths and flood risk occurring

4) Trees can change the physical appearance of Southampton's streets

By planting more street trees, it is hoped that the physical appearance of Southampton's streets can be improved. We would like to know which type (species) and size of trees you, and other local residents, would prefer.

In the tree programme choices that follow, 'change to appearance of Southampton's streets' might take one of four levels:

No change

Small trees (of one species) planted

Large trees (of one species) planted

Mixed trees (of varying species) planted

5) There is a financial cost to planting additional street trees in the city

The proposed tree planting will be paid for by council tax payers through the creation of a new City Tree Fund. Additional payments will be required from **each eligible household** on a yearly basis. These funds will be spent solely on establishing new street trees, covering the costs of planting each tree and ensuring their healthy growth.

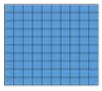
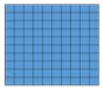
In the choices that follow, you will find that each alternative tree programme has a cost associated with it, ranging from £0 (for '*no* tree programme') to £168 per household per year.

If you don't want to pay for any of the suggested tree programmes, you can choose the '*no* tree programme' option. You can do this for one, some or all of the 12 choices. If the majority of people opt for no tree programme overall, this means you will not have to pay anything extra, but no additional street trees will be planted either (and therefore no health or flood benefits will occur).

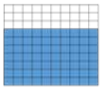
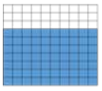
You will now be asked to make 12 choices from a set of similar (but different) combinations of possible tree programmes. Each choice is **independent** of the other choices. In each of these, we would like you to choose the alternative you prefer most and are **willing to pay for**. By choosing to pay for tree planting, you will have less money available for your other expenditures.

Your choices

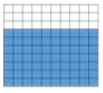
9. Choice 1 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	7 fewer pollution-related deaths	1 fewer pollution-related death	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	300 fewer properties at risk of flooding	500 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	100% chance of reductions in deaths and flood risk occurring 	100% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Small trees planted 	Large trees planted 	No change 
Payment by your household to support new street tree planting in the city	£168 per year (£14 per month)	£24 per year (£2 per month)	£0
Your choice	☐	☐	☐

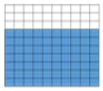
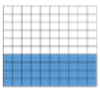
10. Choice 2 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	7 fewer pollution-related deaths	1 fewer pollution-related death	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	100 fewer properties at risk of flooding	500 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	70% chance of reductions in deaths and flood risk occurring 	70% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Large trees planted 	Mixed trees planted 	No change 
Payment by your household to support new street tree planting in the city	£132 per year (£11 per month)	£24 per year (£2 per month)	£0
Your choice	☐	☐	☐

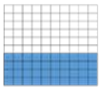
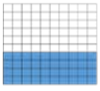
11. Choice 3 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	4 fewer pollution-related deaths	7 fewer pollution-related deaths	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	500 fewer properties at risk of flooding	100 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	70% chance of reductions in deaths and flood risk occurring 	100% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Small trees planted 	Mixed trees planted 	No change 
Payment by your household to support new street tree planting in the city	£60 per year (£5 per month)	£96 per year (£8 per month)	£0
Your choice	☐	☐	☐

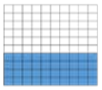
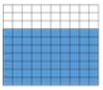
12. Choice 4 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	1 fewer pollution-related death	4 fewer pollution-related deaths	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	100 fewer properties at risk of flooding	300 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	70% chance of reductions in deaths and flood risk occurring 	40% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Mixed trees planted 	Small trees planted 	No change 
Payment by your household to support new street tree planting in the city	£96 per year (£8 per month)	£168 per year (£14 per month)	£0
Your choice	☐	☐	☐

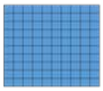
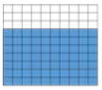
13. Choice 5 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	4 fewer pollution-related deaths	1 fewer pollution-related death	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	300 fewer properties at risk of flooding	300 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	40% chance of reductions in deaths and flood risk occurring 	40% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Large trees planted 	Mixed trees planted 	No change 
Payment by your household to support new street tree planting in the city	£132 per year (£11 per month)	£60 per year (£5 per month)	£0
Your choice	☐	☐	☐

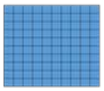
14. Choice 6 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	7 fewer pollution-related deaths	4 fewer pollution-related deaths	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	500 fewer properties at risk of flooding	100 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	40% chance of reductions in deaths and flood risk occurring 	70% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Large trees planted 	Small trees planted 	No change 
Payment by your household to support new street tree planting in the city	£96 per year (£8 per month)	£24 per year (£2 per month)	£0
Your choice	☐	☐	☐

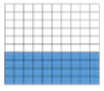
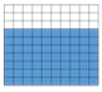
15. Choice 7 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	4 fewer pollution-related deaths	4 fewer pollution-related deaths	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	100 fewer properties at risk of flooding	500 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	100% chance of reductions in deaths and flood risk occurring 	70% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Small trees planted 	Large trees planted 	No change 
Payment by your household to support new street tree planting in the city	£60 per year (£5 per month)	£96 per year (£8 per month)	£0
Your choice	☐	☐	☐

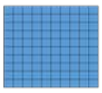
16. Choice 8 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	1 fewer pollution-related death	7 fewer pollution-related deaths	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	500 fewer properties at risk of flooding	100 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	100% chance of reductions in deaths and flood risk occurring 	100% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Small trees planted 	Mixed trees planted 	No change 
Payment by your household to support new street tree planting in the city	£60 per year (£5 per month)	£132 per year (£11 per month)	£0
Your choice	☐	☐	☐

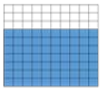
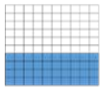
17. Choice 9 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	7 fewer pollution-related deaths	1 fewer pollution-related death	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	500 fewer properties at risk of flooding	300 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	40% chance of reductions in deaths and flood risk occurring 	70% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Mixed trees planted 	Large trees planted 	No change 
Payment by your household to support new street tree planting in the city	£168 per year (£14 per month)	£60 per year (£5 per month)	£0
Your choice	☐	☐	☐

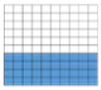
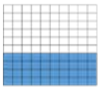
18. Choice 10 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	4 fewer pollution-related deaths	7 fewer pollution-related deaths	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	300 fewer properties at risk of flooding	100 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	100% chance of reductions in deaths and flood risk occurring 	100% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Mixed trees planted 	Small trees planted 	No change 
Payment by your household to support new street tree planting in the city	£24 per year (£2 per month)	£60 per year (£5 per month)	£0
Your choice	☐	☐	☐

19. Choice 11 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	1 fewer pollution-related death	7 fewer pollution-related deaths	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	100 fewer properties at risk of flooding	500 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	70% chance of reductions in deaths and flood risk occurring 	40% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Large trees planted 	Small trees planted 	No change 
Payment by your household to support new street tree planting in the city	£24 per year (£2 per month)	£168 per year (£14 per month)	£0
Your choice	☐	☐	☐

20. Choice 12 – What is your most preferred tree programme - that you are willing to pay for - from the following three alternatives? (Remember that this choice is independent of the other 11 choices).

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	1 fewer pollution-related death	4 fewer pollution-related deaths	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	300 fewer properties at risk of flooding	300 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	40% chance of reductions in deaths and flood risk occurring 	40% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Mixed trees planted 	Large trees planted 	No change 
Payment by your household to support new street tree planting in the city	£24 per year (£2 per month)	£132 per year (£11 per month)	£0
Your choice	☐	☐	☐

Understanding your choices

21. Did you choose the 'no tree programme' in any of the choices?

☐ No – please continue to the next question

☐ Yes – please tell us your main reasons for choosing the 'no tree programme' (tick up to three boxes):

☐ I don't trust the council to deliver the programme successfully

☐ The council should pay for tree planting from existing taxes

☐ Someone else should pay, like businesses, developers or those causing pollution

☐ It's not fair that I should have to pay for tree planting

☐ I can't afford to pay the requested amount

☐ I wouldn't personally benefit from the programme

☐ There are more important things to spend money on than trees

☐ There are better ways to deal with pollution and flood risk than planting trees

☐ The choice questions were too difficult to answer

☐ It is unwise to spend money on something that has an uncertain outcome

22. Did you choose 'Tree programme A' or 'Tree programme B' in any of the choices?

☐ No – please continue to the next question

☐ Yes – please tell us your main reasons for choosing to pay for a tree planting programme (tick up to three boxes):

☐ I think addressing air pollution is important

☐ I think addressing flood risk is important

☐ I appreciate the honesty about the uncertainty and am willing to give the programme the benefit of the doubt

☐ It would make the city a more attractive place to live

☐ I think the proposed tree planting programme is good value for money
☐ I always choose the best option for the environment, regardless of the cost
☐ It makes me feel good to know that I am helping the future of my city
☐ I don't pay council tax, so I won't have to pay for the tree programme
☐ I don't believe that I will really have to pay

23. On a scale of 0 (not at all confident) to 10 (very confident), how confident are you now that planting new trees on Southampton's streets would reduce air pollution in the city?

Not at all confident	0	1	2	3	4	5	6	7	8	9	10	Very confident
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

24. On a scale of 0 (not at all confident) to 10 (very confident), how confident are you now that planting new trees on Southampton's streets would reduce surface water flooding in the city?

Not at all confident	0	1	2	3	4	5	6	7	8	9	10	Very confident
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

25. Do you believe the proposed City Tree Fund will be implemented in Southampton?

☐ Yes
☐ No
☐ Don't know

About you

Please remember that your responses to the questions in this survey are <u>completely anonymous</u>. This section will tell us whether the residents who have responded to this survey are typical of Southampton's population as a whole.

26. How old are you?

☐ 18-22
☐ 23-29
☐ 30-39
☐ 40-49
☐ 50-64
☐ 65+
☐ Prefer not to say

27. What is your gender?

☐ Male
☐ Female
☐ Other
☐ Prefer not to say

28. What is your <u>highest</u> completed level of education?

☐ Level 4 and above, e.g. HND, Degree, Higher Degree, and foreign equivalents

☐ Level 3, e.g. 2 or more A levels, advanced GNVQ, NVQ level 3, and foreign equivalents
☐ Level 2, e.g. 5 or more GCSEs at grades A-C, intermediate GNVQ, NVQ level 2, and foreign equivalents
☐ Level 1, e.g. fewer than 5 GCSEs at grades A-C, foundation GNVQ, NVQ level 1, and foreign equivalents
☐ Other qualifications, e.g. professional or vocational qualifications
☐ No qualifications
☐ Prefer not to say

29. What is your ethnicity?

☐ White British
☐ Other White
☐ Asian/Asian British
☐ Black/African/Caribbean/Black British
☐ Mixed/multiple ethnic group
☐ Other ethnic group
☐ Prefer not to say

30. Are you a member of any environmental charities or associations?

☐ Yes
☐ No

31. In which Southampton ward do you live? [Please click here for a map of the city wards: https://www.southampton.gov.uk/council-democracy/councillors/wards-map.aspx]

☐ Bargate	☐ Freemantle	☐ Shirley
☐ Bassett	☐ Harefield	☐ Sholing
☐ Bevois	☐ Millbrook	☐ Swathling
☐ Bitterne	☐ Peartree	☐ Woolston
☐ Bitterne Park	☐ Portswood	☐ Don't know / prefer not to say
☐ Coxford	☐ Redbridge	

In this survey it is proposed that *households* (people living together at the same address) will pay for the tree programme, rather than individuals. Considering this, please answer the following questions about your household.

32. How many adults live at your address, including you?

_____

33. How many of those receive an income?

_____

34. Approximately how much is the total pre-tax yearly income for your household (it is fine to guestimate the income of any housemates)?

☐ Less than £15,000
☐ £15,000 – £24,999
☐ £25,000 – £39,999
☐ £40,000 – £59,999
☐ £60,000 – £79,999

☐ £80,000 – £99,999
☐ £100,000 or more
☐ Don't know / prefer not to say

Comments and prize draw

If there is anything else you would like to say to the council about tree planting in Southampton, please do so here:

If you wish to enter into the prize draw for a chance to win one of four £50 gift vouchers (accepted in over 130 high street stores), please click on the following link:

https://www.isurvey.soton.ac.uk/29182

This link will open up a separate webpage on the University website where you can enter your name and address. The webpage is completely independent of this tree planting survey – names and addresses entered there cannot be linked to the survey data, and IP addresses will not be tracked. Your responses to the survey will therefore remain completely anonymous.

D.2 Expected utility theory vs. direct utility

Three different versions of Model 2 were estimated, representing direct utility, expected utility, and a combination of the two, referred to as direct-partial expected utility. The utility functions for these are as follows.

Direct utility:

$$U = \alpha + \beta_1 AirQ + \beta_2 Flood + \beta_3 AppLarge + \beta_4 AppMixed + \beta_5 Payment + \beta_6 ObjCert + \mathcal{E} \quad (8)$$

Expected utility:

$$U = \alpha + \beta_1 AirQ*ObjCert + \beta_2 Flood*ObjCert + \beta_3 AppLarge + \beta_4 AppMixed + \beta_5 Payment + \mathcal{E} \quad (12)$$

Direct-partial expected utility:

$$U = \alpha + \beta_1 AirQ + \beta_2 AirQ*ObjCert + \beta_3 Flood + \beta_4 Flood*ObjCert + \beta_5 AppLarge + \beta_6 AppMixed + \beta_7 Payment + \beta_8 ObjCert + \mathcal{E} \quad (13)$$

The model estimations for each of these are shown for comparison in Table D.1.

Table D.1: RPL Model 2, 2b and 2c estimation (comparing expected utility with direct utility)

	Expected utility (2b)		Direct utility (2)		Direct-partial expected utility (2c)	
Attributes	Coefficient (s.e.)	RP std devn (s.e.)	Coefficient (s.e.)	RP std devn (s.e.)	Coefficient (s.e.)	RP std devn (s.e.)
ASC (inc. small trees)	3.166*** (0.169)		1.836*** (0.371)		2.337*** (0.614)	
AirQ (per 1 less death)			0.297*** (0.054)	0.526*** (0.039)	0.328*** (0.094)	0.519*** (0.041)
AirQ*ObjCert (1 death, 10%)	0.035*** (0.007)	0.069*** (0.005)			0.003 (0.010)	0.009 (0.007)
Flood (per 100 fewer prop.)			0.263*** (0.037)	-0.184*** (0.034)	0.096 (0.161)	-0.140 (0.081)
Flood*ObjCert (100 prop, 10%)	0.042*** (0.006)	0.047*** (0.005)			0.027 (0.022)	-0.019 (0.012)
ObjCert (per 10% more certainty)			0.387*** (0.051)	-0.360*** (0.034)	0.334*** (0.090)	0.355*** (0.029)
AppLarge	-0.039 (-0.141)	1.805*** (0.147)	0.087 (0.156)	1.785*** (0.165)	0.085 (0.154)	-1.859*** (0.163)
AppMixed	-0.044 (0.113)	-1.988*** (0.125)	-0.086 (0.112)	-1.110*** (0.125)	-0.081 (0.116)	-1.109*** (0.131)
Payment	-0.280*** (0.017)		-0.339*** (0.027)		-0.351*** (0.029)	
No. of observations	4,068		4,068		4,068	
Log-likelihood	-2011.6		-1829.7		-1829.2	
Adjusted ρ^2	0.34		0.40		0.40	
AIC	4043.2		3683.4		3690.4	
BIC	4102.6		3754.6		3785.4	

*, **, *** represent statistical significance at 10%, 5% and 1% level, respectively

The usual indicators of model fit, such as the Bayesian Information Criteria (BIC), the Akaike Information Criteria (AIC), the adjusted ρ^2, and the likelihood ratio test, can be used to compare nested models (i.e. 2b with 2c, and 2 with 2c). These show Model 2c to fit the data significantly better than Model 2b (LR $p < 0.01$), however there is no clear difference between Models 2 and 2c (LR $p = 0.91$). The relatively poor fit of Model 2b, and the fact that the estimate for ObjCert is significantly positive in Models 2 and 2c, suggests that respondents hold direct utility for improving the level of objective certainty, independent of the environmental outcomes to which it relates. As a result, the data do not support the use of EUT. Furthermore, respondents do not value the interaction effect of uncertainty on air quality/flood outcomes *in addition to* the AirQ, Flood and ObjCert attributes separately, as the estimates for the interaction terms in Model 2c are insignificant.[84] Thus it was considered that the direct utility model should be used for this study.

[84] Surprisingly, Flood has also become insignificant in Model 2c. This may be due to the sample size being too small for a large-parameter model.

D.3 Experience of objective vs. (posterior) subjective uncertainty

As presenting people with information about a PES scheme (either with or without objective uncertainty) may cause them to update their beliefs, it is also useful to see how WTP differs between certain and uncertain outcomes for those who trust or doubt ES provision *a posteriori*. Equation (11) was therefore re-modelled using posterior instead of prior beliefs. The log-likelihood ratio test ($P < 0.001$), the AIC and the BIC all indicate that the model with posterior beliefs fits the data significantly better than the one with prior beliefs (the same finding as was made under RQ3). This is because at the point where respondents make their choices (and reveal their WTP), they have already had the opportunity to update their beliefs based on the objective certainty information contained (or implied) in the choice experiment scenario.

Table D.2: RPL Model 4b estimation and willingness-to-pay (experience of objective vs. posterior subjective uncertainty)

Attributes	Coefficient (s.e.)	Std deviation (s.e.)[a]	Mean WTP (95% CI)[b]
ASC (tree planting programme, inc. small trees)	5.936*** (0.412)		£184.34*** (£149.92, £221.44)
AirQ (per 1 fewer pollution-related death)	0.214*** (0.053)	-0.649*** (0.049)	£6.25*** (£3.99, £8.49)
Flood (per 100 fewer properties at risk of flooding)	0.086*** (0.027)	0.318*** (0.031)	£2.46*** (£0.96, £3.91)
AppLarge (for large rather than small trees)	-0.039 (0.142)	-2.069*** (0.186)	£0 (-£7.87, £8.09)
AppMixed (for mixed rather than small trees)	-0.190 (0.104)	-1.293*** (0.143)	£0 (-£11.58, £2.02)
ObjUncertD (respondents for whom choices reflect outcomes with 40% or 70% objective certainty)	-0.631*** (0.219)		-£18.18*** (-£32.93, -£3.69)
DoubterD (respondents for whom the averaged subjective certainty score is ≤7)	-1.561 *** (0.301)		-£51.14*** (-£84.44, -£18.45)
ObjUncertD*DoubterD (additional effect of objective uncertainty for doubters)	0.244 (0.265)		£0 (-£9.66, £24.43)
Payment	-0.389*** (0.032)		
Treatment scale parameter	0.877*** (0.064)		
Overall programme[c] for truster with certain outcomes (TC)			£193.05 (£159.36, £229.36)
Overall programme[c] for truster with uncertain outcomes (TU)			£174.87 (£147.48, £205.17)
Overall programme[c] for doubter with certain outcomes (DC)			£141.92 (£122.49, £164.46)
Overall programme[c] for doubter with uncertain outcomes (DU)			£123.74 (£101.37, £147.21)
No. of observations	4,068		

Log-likelihood	-2718.2
Adjusted ρ2	0.39
AIC	5464.4
BIC	5552.7

*, **,*** represent statistical significance at 10%, 5% and 1% level, respectively

[a] The random parameters follow a normal distribution

[b] Mean WTP and confidence intervals are calculated per household per year, using Krinksy and Robb (1986) bootstrapping procedures with 2,000 draws

[c] The overall programme is based on the lowest levels of the three ES attributes, i.e. the avoidance of one death and 100 properties at risk of flooding, and for the planting of small trees

In Model 4b, the coefficients for ObjUncertD and DoubterD are both negative, and statistically significant at the 1% level. This means that the presence of objective uncertainty and the presence of a posteriori doubt both significantly lower utility (and WTP) for the tree planting programme compared to a situation where there is objective or subjective *certainty* about ES provision. The fact that DoubterD is now significant at the 1% level (compared to 10% in Model 4) shows that doubting ES provision *after* having seen objective information about the PES scheme has a much greater (negative) effect on utility/WTP for the scheme than does doubting ES provision *before* seeing objective information about the scheme. This could be due to updating of beliefs at respondent level, which is explored in sub-section 5.3.1.2.

Regarding the interaction term, the coefficient is noticeably larger – and positive – compared to that in Model 4, suggesting that some a posteriori doubters may indeed appreciate the improved realism/credibility of an objectively uncertain scheme compared to one that is supposedly certain. However, this effect is still insignificant (resulting in zero marginal WTP), so alternative hypothesis $H_4 3$ must still be rejected. Table D.2 also reveals that the modelled ranking of WTP for the four groups of respondent is the same whether prior or posterior beliefs are used. For Model 4b this was found to be TC ≥ TU > DC ≥ DU. The only difference between this and the ranking for Model 4 is that WTP for trusters with objectively uncertain outcomes (TU) was found to be significantly higher than that for doubters with objectively certain outcomes (DC). This means that alternative hypothesis $H_4 2$ can be accepted in full when posterior beliefs are used.

D.4 Open comments about the proposed tree planting programme

At the end of the survey, respondents were offered the opportunity to make comments to the council about tree planting in Southampton. A total of 69 citizens made comments – at 19% of those who completed the survey, this is relatively high for a survey of this kind (Martin-Ortega *et al.*, 2017). These 69 citizens included 8 of the 33 respondents who were not willing to pay for tree planting in any of the choice questions; 9 of the 65 respondents who were willing to pay in some of the questions; and 52 of the 269 respondents who were willing to pay in all of them. In terms of socio-demographics, those who made comments were significantly older ($\nu = 5$, $\chi 2 = 11.153$, $P = 0.048$) and less well educated ($\nu = 5$, $\chi 2 = 12.296$, $P = 0.031$) than those who did not. The topics raised in the comments are summarised in Table D.3 (note that some respondents mentioned multiple topics).

Table D.3: Summary of respondents' comments about the proposed tree planting programme

Topic raised	No. of comments	Examples of respondents' comments
The programme is a good idea and should go ahead	35	"More trees would be an excellent move for Southampton." "I'd be very pleased if the council would start such a programme to help protect the local environment and peoples' health." "All political parties need to be on board so that it happens and makes a difference to the city." "Please make this tree program work, it's good for everyone."
New trees must be properly maintained	16	"It's important to consider ongoing maintenance of any new tree planting to ensure their long term establishment." "As long as you keep them at a sensible height and width." "Locally trees have been planted but they have been destroyed by vandals. Nothing is ever done to punish these people." "Lovely idea, but will they be looked after?"
Tree nuisances of particular importance	14	"Our trees block a lot of sunlight and this has [a negative] effect on my wellbeing." "The roots can be a trip hazard from personal experience. Also trees could be an impediment for those with walking disabilities." "Trees will only cause more waste on the streets in the autumn to clean up."
Concerns over council's ability to deliver the programme	10	"If [the council] looked after what we already have, then more people would be a lot happier with having more trees planted." "I've lived in Soton now for 40 years and I'm appalled how the council has failed to manage its trees during that time." "I don't think the council is capable of carrying out the scheme to anywhere near a satisfactory level, so I am not willing to have my money wasted."
Tree benefits of particular importance	10	"Shirley High Street is crying out for large trees along it to improve the appearance and air quality." "I believe that planting trees will absolutely help reduce pollution and make the city more attractive." "A mixture of species… would provide a more varied habitat for wildlife."
Better things to spend money on than planting street trees	9	"There are outstanding issues such as road repairs which may take presidency." "City drainage could be improved by council 'incentives' for local residents not to pave over their gardens." "Reducing the number of traffic lights and speed humps plus improving traffic management in the city… would be more productive in reducing air pollution."

Topic raised	No. of comments	Examples of respondents' comments
Need to plant the right trees in the right places	8	"The species, number and position of trees on any street should be decided by professionals with appropriate environmental qualifications." "I wouldn't want to have any really tall trees planted in front of my property. Can the council plant more tall trees in the parks and open spaces?"
Funding sources other than raising council tax should be used	7	"If the council are going to fine vehicles [through the proposed 'Clean Air Zone']… these fines should be used to finance a tree planting scheme and therefore no increase in the council tax should be involved." "Adding additional things to council tax will eventually out-price those people that live in deprivation in our city. A contribution fund where people can [voluntarily] add the price of a tree might be one option."
The programme is a bad idea and should not go ahead	6	"Trees would make matters worse with leaves clogging currently clear drains… Tree lined roads are not the answer in my opinion and I am reluctant to pay to make matters worse." "Where I live, the trees are a nightmare, they are so overgrown, never maintained. Even when complained about, leaves are never cleaned up, block up drains, and if we plant any more, it will cause more of a problem… That's why I would be against it."
Concern about future funding of the programme	4	"[People] have to be convinced this is exactly where the funds will be directed, and ensure they are not diverted at some time in the future to fill a shortfall in some other pot."
Want more involvement in the programme	3	"A lot of urban dwellers and home owners have green fingers and would love the idea of helping out on each street."
Dislike uncertainty around tree benefits	1	"I would be willing to pay… if the likelihood of impact was high (70%-100%) AND it would affect the highest number of houses (500) and/or some people. I would not be willing to pay… [for the] lower chance of benefit to a smaller number of houses and/or only 1 person."

List of References

Abhijith, K.V., Kumar, P., Gallagher, J., Mcnabola, A., Baldauf, R., Pilla, F., Broderick, B., Di Sabatino, S. and Pulvirenti, B. (2017) Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments – A review. *Atmospheric Environment,* 162 (Supplement C), 71-86.

Adhikari, D., Thacher, J.A., Chermak, J.M. and Berrens, R.P. (2017) Linking Forest to Faucets in a Distant Municipal Area: Public Support for Forest Restoration and Water Security in Albuquerque, New Mexico. *Water Economics and Policy,* 3 (1), 1650019-1650011:1650034.

Aguilar, F.X., Obeng, E.A. and Cai, Z. (2018) Water quality improvements elicit consistent willingness-to-pay for the enhancement of forested watershed ecosystem services. *Ecosystem Services,* 30, 158-171.

Ainscough, J., Wilson, M. and Kenter, J.O. (2018) Ecosystem services as a post-normal field of science. *Ecosystem Services,* 31, 93-101.

Akerlof, G.A. and Dickens, W.T. (1982) The Economic Consequences of Cognitive Dissonance. *The American Economic Review,* 72 (3), 307-319.

Akter, S., Bennett, J. and Ward, M.B. (2012) Climate change scepticism and public support for mitigation: Evidence from an Australian choice experiment. *Global Environmental Change,* 22 (3), 736-745.

Andersson, E., Barthel, S., Borgstrom, S., Colding, J., Elmqvist, T., Folke, C. and Gren, A. (2014) Reconnecting cities to the biosphere: stewardship of green infrastructure and urban ecosystem services. *Ambio,* 43 (4), 445-453.

Andrews, B., Ferrini, S. and Bateman, I. (2017) Good parks – bad parks: the influence of perceptions of location on WTP and preference motives for urban parks. *Journal of Environmental Economics and Policy,* 6 (2), 204-224.

Armson, D., Stringer, P. and Ennos, A.R. (2013) The effect of street trees and amenity grass on urban surface water runoff in Manchester, UK. *Urban Forestry & Urban Greening,* 12 (3), 282-286.

Ashley, R., Gersonius, B., Digman, C., Horton, B., Smith, B. and Shaffer, P. (2018) Including uncertainty in valuing blue and green infrastructure for stormwater management. *Ecosystem Services,* 33, 237-246.

Ayres, S. (2019) How can network leaders promote public value through soft metagovernance? *Public Administration,* 97 (2), 279-295.

Bade, T., Andersson, E., Adams, C., Triple Me and Src (2015) *Nature as a firm: Towards a sustainable financial basis for ecosytem service provisioning based on the Coase Theorem*. Green Surge.

Baden, D. (2016) A reconstruction of Carroll's pyramid of corporate social responsibility for the 21st century. *International Journal of Corporate Social Responsibility,* 1 (1).

Barbrook, J., Mackenzie, R., Doick, K.J., Griffiths, A., Salisbury, A. and Smith, J.C. (2018) *The Right Tree in the Right Place for a Resilient Future*. London, UK: Defra.

Barcelona City Council (2011) *Street Tree Management in Barcelona*. Barcelona, Spain: Barcelona City Council.

Barker, A. and Pina-Sánchez, J. (2019) *CHARITABLE GIVING TO PARKS AND GREEN SPACES: Public and business opinion in Leeds, UK*. Leeds: Leeds, U.O.

Barnaud, C. and Antona, M. (2014) Deconstructing ecosystem services: Uncertainties and controversies around a socially constructed concept. *Geoforum,* 56 (Supplement C), 113-123.

Baró, F., Bugter, R., Gómez-Baggethun, E., Hauck, J., Kopperoinen, L., Liquete, C. and Potschin, M. (2015) Green Infrastructure IN: Potschin, M. and Jax, K. (eds.) *OpenNESS Ecosystem Service Reference Book*. Available via: www.openness-project.eu/library/reference-book.

Baró, F., Palomo, I., Zulian, G., Vizcaino, P., Haase, D. and Gómez-Baggethun, E. (2016) Mapping ecosystem service capacity, flow and demand for landscape and urban planning: A case study in the Barcelona metropolitan region. *Land Use Policy,* 57, 405-417.

Bartczak, A., Mariel, P., Chilton, S. and Meyerhoff, J. (2016) The impact of latent risk preferences on valuing the preservation of threatened lynx populations in Poland. *Australian Journal of Agricultural and Resource Economics,* 60 (2), 284-306.

Barton, D.N. (2015) Monetary valuation of urban ecosystem services - operationalization or tragedy of well-intentioned valuation? An illustrated example. IN: Nuss-Girona, S. and Castañer, M. (eds.) *Ecosystem services: concepts, methodologies and instruments for research and applied use*. Girona, Spain: Documenta Universitaria, 65-85.

Barton, D.N., Benavides, K., Chacon-Cascante, A., Le Coq, J.-F., Quiros, M.M., Porras, I., Primmer, E. and Ring, I. (2017) Payments for Ecosystem Services as a Policy Mix: Demonstrating the institutional analysis and development framework on conservation policy instruments. *Environmental Policy and Governance,* 27 (5), 404-421.

Bateman, I., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Ozdemiroglu, E., Pearce, D., Sugden, R. and Swanson, J. (2002) *Economic valuation with stated preference techniques: A Manual*. Cheltenham, UK: Edward Elgar.

Ben-Akiva, M., Mcfadden, D., Train, K., Walker, J., Bhat, C., Bierlaire, M., Bolduc, D., Boersch-Supan, A., Brownstone, D., Bunch, D.S., Daly, A., De Palma, A., Gopinath, D., Karlstrom, A. and Munizaga, M.A. (2002) Hybrid Choice Models: Progress and Challenges. *Marketing Letters,* 13 (3), 163-175.

Bendor, T.K., Livengood, A., Lester, T.W., Davis, A. and Yonavjak, L. (2015) Defining and evaluating the ecological restoration economy. *Restoration Ecology,* 23 (3), 209-219.

Bennett, D.E., Gosnell, H., Lurie, S. and Duncan, S. (2014) Utility engagement with payments for watershed services in the United States. *Ecosystem Services,* 8, 56-64.

Bennett, E.M., Peterson, G.D. and Gordon, L.J. (2009) Understanding relationships among multiple ecosystem services. *Ecology Letters,* 12 (12), 1394-1404.

Bernoulli, D. (1738) Specimen Theoriae Novae th Mensura Sortis. *Commentarii Academiae Scientiarum Imperiales Petropolitanae,* 5, 71-192.

Bevan, G. and Hood, C. (2006) What's Measured is What Matters: Targets and Gaming in the English Public Health Care System. *Public Administration,* 84 (3), 517-538.

Bhagwat, S.A., Humphreys, D. and Jones, N. (2017) Forest governance in the Anthropocene: Challenges for theory and practice. *Forest Policy and Economics,* 79, 1-7.

Binner, A., Smith, G., Bateman, I., Day, B., Agarwala, M. and Harwood, A. (2017) *Forestry Commission Research Report: Valuing the social and environmental contribution of woodlands and trees in England, Scotland and Wales*. Edinburgh: Forestry Commission.

Birmingham City Council (2013) *Birmingham's Green Living Spaces Plan*. Birmingham: Birmingham City Council. Available from: http://www.birmingham.gov.uk/greenlivingspaces.

Birmingham City Council (2018) *Birmingham Tree Policy*. Birmingham, UK: Birmingham City Council. Available from: https://www.birmingham.gov.uk/downloads/file/9309/birmingham_tree_policy.

Birol, E., Koundouri, P. and Kountouris, Y. (2009) Using the choice experiment method to in- form river management in Poland: flood risk reduction versus habitat conservation in the Upper Silesia region IN: Birol, E. and Koundouri, P. (eds.) *Choice Experiments Informing Environmental Policy. A European Perspective.* . Cheltenham (UK) and Northampton (USA): Edward Elgar Publishing.

Bliemer, M.C.J. (2016) *Choice modelling and stated choice survey design*. London, 14-18 November 2016.

Bliemer, M.C.J. and Rose, J.M. (2013) Confidence intervals of willingness-to-pay for random coefficient logit models. *Transportation Research Part B: Methodological,* 58, 199-214.

Bodnaruk, E.W., Kroll, C.N., Yang, Y., Hirabayashi, S., Nowak, D.J. and Endreny, T.A. (2017) Where to plant urban trees? A spatially explicit methodology to explore ecosystem service tradeoffs. *Landscape and Urban Planning,* 157, 457-467.

Bolduc, D., Ben-Akiva, M., Walker, J. and Michaud, A. (2005) Hybrid choice models with logit kernel: applicability to large scale models. *Integrated Land-Use and Transportation Models: Behavioural Foundations*, 275-302.

Bonn, A., Reed, M.S., Evans, C.D., Joosten, H., Bain, C., Farmer, J., Emmer, I., Couwenberg, J., Moxey, A., Artz, R., Tanneberger, F., Von Unger, M., Smyth, M.-A. and Birnie, D. (2014) Investing in nature: Developing ecosystem service markets for peatland restoration. *Ecosystem Services,* 9, 54-65.

Börger, T. (2015) Are Fast Responses More Random? Testing the Effect of Response Time on Scale in an Online Choice Experiment. *Environmental and Resource Economics,* 65 (2), 389-413.

Börger, T. and Hattam, C. (2017) Motivations matter: Behavioural determinants of preferences for remote and unfamiliar environmental goods. *Ecological Economics,* 131, 64-74.

Botzen, W.J.W., Aerts, J.C.J.H. and Van Den Bergh, J.C.J.M. (2009) Willingness of homeowners to mitigate climate risk through insurance. *Ecological Economics,* 68 (8-9), 2265-2277.

Botzen, W.J.W. and Van Den Bergh, J.C.J.M. (2012) Risk attitudes to low-probability climate change risks: WTP for flood insurance. *Journal of Economic Behavior & Organization,* 82 (1), 151-166.

Bournemouth Borough Council (2014) *Bournemouth Tree Strategy 2014-24*. Bournemouth, UK: Bournemouth Borough Council.

Boyne, G.A. and Walker, R.M. (2004) Strategy Content and Public Service Organizations. *Journal of Public Administration Research and Theory,* 14 (2), 231-252.

Braun, V. and Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative Research in Psychology,* 3 (2), 77-101.

Brewer, T.R., Mant, J., Harris, J., Gill, A., Shaw, H., Burgess, P.J. and Farewell, T. (2014) *Improving the River Lea in Luton for the local economy, society and environment. Final Report to Defra.* Cranfield: Cranfield University.

Brey, R., Riera, P. and Mogas, J. (2007) Estimation of forest values using choice modeling: An application to Spanish forests. *Ecological Economics,* 64 (2), 305-312.

Britt, C. and Johnston, M. (2008) *Trees In Towns II: A new survey of urban trees in England and their condition and management*. London: Department for Communities and Local Government,.

Brouwer, R. and Schaafsma, M. (2013) Modelling risk adaptation and mitigation behaviour under different climate change scenarios. *Climatic Change,* 117 (1-2), 11-29.

Bryson, J., Sancino, A., Benington, J. and Sørensen, E. (2017) Towards a multi-actor theory of public value co-creation. *Public Management Review,* 19 (5), 640-654.

Bunse, L., Rendon, O. and Luque, S. (2015) What can deliberative approaches bring to the monetary valuation of ecosystem services? A literature review. *Ecosystem Services,* 14, 88-97.

Burghart, D.R., Cameron, T.A. and Gerdes, G.R. (2007) Valuing publicly sponsored research projects: Risks, scenario adjustments, and inattention. *Journal of Risk and Uncertainty,* 35 (1), 77-105.

Burn, C. (2018) Sheffield Council has been forced to reveal a hugely-controversial PFI highways maintenance contract contains a target to cut down almost half of the city's 36,000 street trees and replace them with saplings. *The Yorkshire Post*. Available from: https://www.yorkshirepost.co.uk/our-region/south-yorkshire/sheffield/sheffield-council-forced-to-reveal-target-to-remove-17-500-street-trees-under-pfi-deal-1-9056942 [Accessed 9th June 2018].

Camargue (2015) *Woodland Carbon Code Marketing and Advocacy Strategy. Version 1. Unpublished report submitted to the Forestry Commission*.

Cambridge City Council (2016) *Citywide Tree Strategy 2016-2026*. Cambridge: Cambridge City Council.

Cambridge Dictionary (2019) Meaning of value in English. Online: Cambridge University Press. Available from: https://dictionary.cambridge.org/dictionary/english/value.

Cameron, T.A. (2005) Updating Subjective Risks in the Presence of Conflicting Information: An Application to Climate Change. *Journal of Risk and Uncertainty,* 30 (1), 63-97.

Campbell, L.K. and Gabriel, N. (2016) Power in urban social-ecological systems: Governance, knowledge production, and marginalization. *Urban Forestry & Urban Greening*.

Capotorti, G., Del Vico, E., Anzellotti, I. and Celesti-Grapow, L. (2016) Combining the Conservation of Biodiversity with the Provision of Ecosystem Services in Urban Green Infrastructure

Planning: Critical Features Arising from a Case Study in the Metropolitan Area of Rome. *Sustainability,* 9 (1), 10.

Carson, R. and Czajkowski, M. (2014) The discrete choice experiment approach to environmental contingent valuation IN: Hess, S. and Daly, A. (eds.) *Handbook of Choice Modelling*. Cheltenham, UK: Edward Elgar Publishing, 202-235.

Carson, R.T., Groves, T. and List, J.A. (2014) Consequentiality: A theoretical and experimental exploration of a single binary choice. *Journal of the Association of Environmental and Resource Economists,* 1, 171.

Ccera Committee (2017) *Branching out: a new ambition for woodland policies*. Cardiff: National Assembly for Wales.

Champion, T. (2014) *People in cities: the numbers*. London: Foresight - Government Office for Science.

Chan, K.M., Balvanera, P., Benessaiah, K., Chapman, M., Diaz, S., Gomez-Baggethun, E., Gould, R., Hannahs, N., Jax, K., Klain, S., Luck, G.W., Martin-Lopez, B., Muraca, B., Norton, B., Ott, K., Pascual, U., Satterfield, T., Tadaki, M., Taggart, J. and Turner, N. (2016) Opinion: Why protect nature? Rethinking values and the environment. *Proceedings of the National Academy of Sciences,* 113 (6), 1462-1465.

Chan, K.M.A., Anderson, E., Chapman, M., Jespersen, K. and Olmsted, P. (2017) Payments for Ecosystem Services: Rife With Problems and Potential—For Transformation Towards Sustainability. *Ecological Economics,* 140, 110-122.

Chan, K.M.A., Gould, R.K. and Pascual, U. (2018) Editorial overview: Relational values: what are they, and what's the fuss about? *Current Opinion in Environmental Sustainability,* 35, A1-A7.

Chen, B. and Qi, X. (2018) Protest response and contingent valuation of an urban forest park in Fuzhou City, China. *Urban Forestry & Urban Greening*.

Chen, W.Y. and Jim, C.Y. (2008) Cost–benefit analysis of the leisure value of urban greening in the new Chinese city of Zhuhai. *Cities,* 25 (5), 298-309.

Choicemetrics (2018) Ngene. ChoiceMetrics. Available from: http://choice-metrics.com/download.html.

City Forest Credits (2017) *Carbon+ Credits for City Trees*. Available from: http://www.cityforestcredits.org/carbon-credits/ [Accessed 19th February, 2018].

City of Helsinki (2014) *Urban Tree Policy*. Helsinki, Finland: City of Helsinki.

City of Melbourne (2012) *Urban Forest Strategy: Making a Great City Greener 2012-2032*. Melbourne, Australia: City of Melbourne.

City of Melbourne (2018) *Support the Urban Forest Fund*. Available from: http://www.melbourne.vic.gov.au/community/parks-open-spaces/urban-forest-fund/Pages/support-urban-forest-fund.aspx [Accessed 19th February, 2018].

Cles and Twt (2015) *Payment for ecosystem services – Irwell catchment. Final report for Defra.*: Centre for Local Economic Strategies and The Wildlife Trusts.

Cllr Rayment (2018) to Davies, H., 12th September 2018.

Committee on Climate Change (2017) *UK Climate Change Risk Assessment 2017 Synthesis report: priorities for the next five years.* London: Committee on Climate Change.

Companies House (2016) *Life of a company – part 1 annual requirements. Version 4.6*. London, UK: Companies House.

Convention on Biological Diversity (2000) *Decisions adopted by the conference of the parties to the Convention on Biological Diversity at its fifth meeting; The Ecosystem Approach. UNEP/CBD/COP/5/23. Decision V/6.* Nairobi, Kenya.

Conway, T.M. and Yip, V. (2016) Assessing residents' reactions to urban forest disservices: A case study of a major storm event. *Landscape and Urban Planning,* 153, 1-10.

Corner, A., Whitmarsh, L. and Xenias, D. (2012) Uncertainty, scepticism and attitudes towards climate change: biased assimilation and attitude polarisation. *Climatic Change,* 114 (3-4), 463-478.

Corona, P. (2016) Consolidating new paradigms in large-scale monitoring and assessment of forest ecosystems. *Environmental Research,* 144 (Pt B), 8-14.

Cortinovis, C. and Geneletti, D. (2018) Ecosystem services in urban plans: What is there, and what is still needed for better decisions. *Land Use Policy,* 70, 298-312.

Costanza, R., D'arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and Van Den Belt, M. (1997) The value of the world's ecosystem services and natural capital. *Nature,* 387 (6630), 253-260.

Costanza, R., De Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Farber, S. and Grasso, M. (2017) Twenty years of ecosystem services: How far have we come and how far do we still need to go? *Ecosystem Services,* 28, 1-16.

Costanza, R., De Groot, R., Sutton, P., Van Der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S. and Turner, R.K. (2014) Changes in the global value of ecosystem services. *Global Environmental Change,* 26, 152-158.

Cpre Sussex (2019) *Plant Your Postcode*. Available from: https://plantyourpostcode.org/.

Cuff, M. (2016) *ClientEarth issues final legal warning to Defra over air pollution plans*. Available from: http://www.businessgreen.com/bg/news/2449050/clientearth-issues-final-legal-warning-to-defra-over-air-pollution-plans [Accessed 18th April 2016].

Czajkowski, M., Hanley, N. and Lariviere, J. (2016) Controlling for the Effects of Information in a Public Goods Discrete Choice Model. *Environmental and Resource Economics,* 63 (3), 523-544.

Czajkowski, M., Hanley, N. and Nyborg, K. (2017) Social Norms, Morals and Self-interest as Determinants of Pro-environment Behaviours: The Case of Household Recycling. *Environmental and Resource Economics,* 66 (4), 647-670.

Daera-Ni (no date) *Forestry planning*. Available from: https://www.daera-ni.gov.uk/articles/forest-planning#toc-1 [Accessed 29th January 2019].

Dahlsrud, A. (2008) How corporate social responsibility is defined: an analysis of 37 definitions. *Corporate Social Responsibility and Environmental Management,* 15 (1), 1-13.

Daily Echo (2018) Car submerged as flash floods hit Southampton. *Daily Echo*, 23rd April 2018. Available from: https://www.dailyecho.co.uk/news/16176118.photos-car-submerged-as-flash-floods-hit-southampton/.

Daily, G.C. (1997) Introduction: what are ecosystem services? IN: Daily, G.C. (ed.) *Natures services: societal dependence on natural ecosystems*. Washington D.C.: Island Press, 1-10.

Dallimer, M., Tang, Z., Bibby, P.R., Brindley, P., Gaston, K.J. and Davies, Z.G. (2011) Temporal changes in greenspace in a highly urbanized region. *Biology Letters,* 7 (5), 763-766.

Darke, R. (2019) *TreeTime Edinburgh*. Oxford, 31st January 2019.

Davies, H. (2017a) Enhancing Welsh woodlands: Assembly Committee publishes report. Cardiff: National Assembly for Wales Policy and Legislation Committee Service. Available from: https://seneddresearch.blog/2017/07/27/enhancing-welsh-woodlands-assembly-committee-publishes-report/

Davies, H. (2017b) *Woodland Creation in European Countries (Research Briefing)*. Cardiff, UK: National Assembly for Wales Research Service.

Davies, H. and Dobbs, W. (2017) *The Planning Series: 16 - Habitats Regulations Assessment (Research Briefing)*. Cardiff, UK National Assembly for Wales Research Service.

Davies, H. and Doick, K. (2017) Valuing the carbon sequestration and rainwater interception ecosystem services provided by Britain's urban trees. Paper presented at Nature-based Solutions to Climate Change in Urban Areas and their Rural Surroundings, Bonn, Germany, 17-19 November 2015.

Davies, H., Doick, K., Handley, P., O'brien, L. and Wilson, J. (2017a) *Forestry Commission Research Report: Delivery of Ecosystem Services by Urban Forests*. Edinburgh: Forestry Commission.

Davies, H.J., Doick, K.J., Hudson, M.D., Schaafsma, M., Schreckenberg, K. and Valatin, G. (2018) Business attitudes towards funding ecosystem services provided by urban forests. *Ecosystem Services,* 32, 159-169.

Davies, H.J., Doick, K.J., Hudson, M.D. and Schreckenberg, K. (2017b) Challenges for tree officers to enhance the provision of regulating ecosystem services from urban forests. *Environmental Research,* 156, 97-107.

Davies, L., Kwiatkowski, L., Gaston, K.J., Beck, H., Brett, H., Batty, M., Scholes, L., Wade, R., Sheate, W.R., Sadler, J., Perino, G., Andrews, B., Kontoleon, A., Bateman, I. and Harris, J.A. (2011) Chapter 10: Urban IN: Nea, U. (ed.) *UK National Ecosystem Assessment Technical Report*. Cambridge: UNEP-WCMC, 361-410.

Dclg (2012) *National Planning Policy Framework*. London, UK: Department for Communities and Local Government. Available from: https://webarchive.nationalarchives.gov.uk/20180608095821/https://www.gov.uk/government/publications/national-planning-policy-framework--2.

De Groot, J.I.M. and Steg, L. (2008) Value Orientations to Explain Beliefs Related to Environmental Significant Behaviour.pdf>. *Environment and Behavior,* 40 (3), 330-354.

De Sario, M., Katsouyanni, K. and Michelozzi, P. (2013) Climate change, extreme weather events, air pollution and respiratory health in Europe. *The European Respiratory Journal,* 42 (3), 826-843.

Defra (2007) *A Strategy for England's Trees, Woods and Forests*. London: Defra.

Defra (2013a) *Government Forestry and Woodlands Policy Statement: Incorporating the Government's Response to the Independent Panel on Forestry's Final Report*. London, UK: Defra.

Defra (2013b) *The National Adaptation Programme: Making the country resilient to a changing climate*. London: Hm Government.

Defra (2014a) *Ecosystem services: Guidance for policy and decision makers on using an ecosystems approach and valuing ecosystem services.* Available from: https://www.gov.uk/guidance/ecosystems-services [Accessed 10th March 2017].

Defra (2014b) *Official Statistics: 2011 Rural-Urban Classification of Local Authorities and other geographies.* Available from: https://www.gov.uk/government/statistics/2011-rural-urban-classification-of-local-authority-and-other-higher-level-geographies-for-statistical-purposes [Accessed 19th August 2016].

Defra (2015a) *The Government announces plans to improve air quality in cities*. Available from: https://www.gov.uk/government/news/improving-air-quality-in-cities [Accessed 15/09/2017].

Defra (2015b) *Modelled background pollution data*. Defra. Available from: https://uk-air.defra.gov.uk/data/pcm-data.

Defra (2016a) *Defra's Payments for Ecosystem Services Pilot Projects 2012-15: Review of key findings*. Defra.

Defra (2016b) *Rural Urban Classification*. Available from: https://www.gov.uk/government/collections/rural-urban-classification [Accessed 20th February 2019].

Defra (2018a) *A Green Future: Our 25 Year Plan to Improve the Environment*. London: HM Government,. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf.

Defra (2018b) Landmark Agriculture Bill to deliver a Green Brexit. HM Government,. Available from: https://www.gov.uk/government/news/landmark-agriculture-bill-to-deliver-a-green-brexit.

Defra (2018c) *Protecting and enhancing England's trees and woodlands: Consultation*. London: Defra.

Dekker, T., Hess, S., Brouwer, R. and Hofkes, M. (2016) Decision uncertainty in multi-attribute stated preference studies. *Resource and Energy Economics,* 43 (Supplement C), 57-73.

Delavande, A. (2008) Measuring revisions to subjective expectations. *Journal of Risk and Uncertainty,* 36 (1), 43-82.

Derissen, S. and Quaas, M.F. (2013) Combining performance-based and action-based payments to provide environmental goods under uncertainty. *Ecological Economics,* 85 (Supplement C), 77-84.

Derkzen, M.L., Van Teeffelen, A.J.A. and Verburg, P.H. (2017) Green infrastructure for urban climate adaptation: How do residents' views on climate impacts and green infrastructure shape adaptation preferences? *Landscape and Urban Planning,* 157, 106-130.

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Brondizio, E., Chan, K.M.A., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Pérez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, S.T., Asfaw, Z., Bartus, G., Brooks, L.A., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A., Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y. and Zlatanova, D. (2015) The IPBES Conceptual Framework — connecting nature and people. *Current Opinion in Environmental Sustainability,* 14, 1-16.

Dickinson, D.C. and Hobbs, R.J. (2017) Cultural ecosystem services: Characteristics, challenges and lessons for urban green space research. *Ecosystem Services,* 25, 179-194.

Dietz, S. and Atkinson, G. (2010) The Equity-Efficiency Trade-off in Environmental Policy: Evidence from Stated Preferences. *Land Economics,* 86 (3), 423-443.

Dobbs, C., Escobedo, F.J. and Zipperer, W.C. (2011) A framework for developing urban forest ecosystem services and goods indicators. *Landscape and Urban Planning,* 99 (3-4), 196-206.

Dobbs, C., Kendal, D. and Nitschke, C.R. (2014) Multiple ecosystem services and disservices of the urban forest establishing their connections with landscape structure and sociodemographics. *Ecological Indicators,* 43, 44-55.

Doick, K., Albertini, A., Handley, P., Lawrence, V., Rogers, K. and Rumble, H. (2016a) *Valuing the Urban Trees in Bridgend County Borough*. Farnham, UK: Forest Research.

Doick, K. and Hutchings, T. (2013) *Air temperature regulation by urban trees and green infrastructure*. Forestry Commission.

Doick, K.J. and Davies, H.J. (2016) What are urban forests and how beneficial are they? *ARB Magazine*. Stonehouse, Gloucestershire: Arboricultural Association,, 48-50.

Doick, K.J., Davies, H.J., Handley, P., Vaz Monteiro, M., O'brien, L. and Ashwood, F. (2016b) *Introducing England's urban forests.*: Urban Forestry and Woodlands Advisory Committee's Network.

Doick, K.J., Davies, H.J., Moss, J., Coventry, R., Handley, P., Rogers, K. and Simpkin, P. (2017) The Canopy Cover of England's Towns and Cities: baselining and setting targets to improve human health and well-being. Paper presented at Trees, People and the Built Environment III, Birmingham.

Doick, K.J., Neilan, C., Jones, G., Allison, A., Mcdermott, I., Tipping, A. and Haw, R. (2018) CAVAT (Capital Asset Value for Amenity Trees): valuing amenity trees as public assets. *Arboricultural Journal,* 40 (2), 67-91.

Donovan, G.H. (2017) Including public-health benefits of trees in urban-forestry decision making. *Urban Forestry & Urban Greening,* 22, 120-123.

Drayson, K. and Newey, G. (2013) *Park Land: How open data can improve our urban green spaces*. London: Policy Exchange.

Dublin City Council (2016) *Dublin City Tree Strategy 2016-2020*. Dublin, Ireland: Dublin City Council.

Duke, J.M., Bruck, J., Barton, S., Murray, M., Inamdar, S. and Tallamy, D.W. (2016) Public preferences for ecosystem services on exurban landscapes: A case study from the Mid-Atlantic, USA. *Heliyon,* 2 (7), e00127.

Eftec (2018) *Natural Capital Account for Greater Manchester*. London, UK: Environment Agency.

Eigenbrod, F., Bell, V.A., Davies, H.N., Heinemeyer, A., Armsworth, P.R. and Gaston, K.J. (2011) The impact of projected increases in urbanization on ecosystem services. *Proceedings of the Royal Society B,* 278 (1722), 3201-3208.

Engel, S., Pagiola, S. and Wunder, S. (2008) Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological Economics,* 65 (4), 663-674.

Environment Agency (2014) *Flood and coastal erosion risk management: Long-term investment scenarios (LTIS) 2014*. Bristol, UK: Environment Agency.

Environment Agency (2016) *Risk of Flooding from Surface Water* Bristol, UK: Environment Agency.

Environmental Audit Committee (2016) *Flooding: Cooperation across Government*. London, UK: House of Commons.

Escobar, M.M., Hollaender, R. and Pineda Weffer, C. (2013) Institutional durability of payments for watershed ecosystem services: Lessons from two case studies from Colombia and Germany. *Ecosystem Services,* 6, 46-53.

Escobedo, F.J., Giannico, V., Jim, C.Y., Sanesi, G. and Lafortezza, R. (2019) Urban forests, ecosystem services, green infrastructure and nature-based solutions: Nexus or evolving metaphors. *Urban Forestry & Urban Greening,* 37, 3-12.

Escobedo, F.J. and Nowak, D.J. (2009) Spatial heterogeneity and air pollution removal by an urban forest. *Landscape and Urban Planning,* 90 (3-4), 102-110.

Esri (2016) ArcGIS Desktop: ArcMap*,* 10.5 ed. Redlands, CA: Environmental Systems Research Institute Inc.,. Available from: http://desktop.arcgis.com/en/arcmap/.

European Commission (2001) *Green Paper: Promoting a European Framework for Corporate Social Responsibilities*. Brussels, Belgium: Commission of the European Communities.

European Commission (2011) *Our life insurance, our natural capital: An EU biodiversity strategy to 2020*. Brussels, Belgium: European Commission.

European Commission (2013) *Green Infrastructure (GI) — Enhancing Europe's Natural Capital*. Brussels: European Commission.

European Commission (2015) *Nature-Based Solutions & Re-Naturing Cities: Final Report of the Horizon 2020 Expert Group*. Brussels: European Commission.

European Environment Agency (2016a) *Urban adaptation to climate change in Europe 2016 - transforming cities in a changing climate*. Copenhagen, Denmark: Eurpean Environment Agency.

European Environment Agency (2016b) *Urban adaptation to climate change in Europe 2016 — Transforming cities in a changing climate*. Luxembourg: European Environment Agency, 12/2016.

Eurostat (2016) *Urban Europe: Statistics on cities, towns and suburbs*. Luxembourg: European Commission. Available from: http://ec.europa.eu/eurostat/en/web/products-statistical-books/-/KS-01-16-691.

Eves, C., Couldrick, L., Everard, M., Reed, M., Carlisle, D. and Mcnab, D. (2015) *Developing the Evidence Base on PES Beneficiaries in England*. London: Urs Infrastructure & Environment Uk Limited.

Faccioli, M. and Czajkowski, M. (2018) Environmental attitudes and place identity as simultaneous determinants of preferences for environmental goods. Paper presented at Envecon 2018, London.

Faccioli, M., Kuhfuss, L. and Czajkowski, M. (2018) Stated Preferences for Conservation Policies Under Uncertainty: Insights on the Effect of Individuals' Risk Attitudes in the Environmental Domain. *Environmental and Resource Economics*, 33.

Faehnle, M., Soderman, T., Schulman, H. and Lehvavirta, S. (2015) Scale-sensitive integration of ecosystem services in urban planning. *Geojournal,* 80 (3), 411-425.

Farley, J. and Costanza, R. (2010) Payments for ecosystem services: From local to global. *Ecological Economics,* 69 (11), 2060-2068.

Farrugia, S., Hudson, M.D. and Mcculloch, L. (2013) An evaluation of flood control and urban cooling ecosystem services delivered by urban green infrastructure. *International Journal of Biodiversity Science, Ecosystem Services & Management,* 9 (2), 136-145.

Ferrini, S. and Scarpa, R. (2007) Designs with a priori information for nonmarket valuation with choice experiments: A Monte Carlo study. *Journal of Environmental Economics and Management,* 53 (3), 342-363.

Festinger, L. (1957) *A theory of cognitive dissonance*. Stanford, CA: Stanford University Press,.

Fisher, B., Bateman, I. and Turner, R.K. (2011) *Valuing Ecosystem Services: Benefits, Values, Space and Time*. Nairobi: Unep.

Fisher, J.A., Patenaude, G., Meir, P., Nightingale, A.J., Rounsevell, M.D.A., Williams, M. and Woodhouse, I.H. (2013) Strengthening conceptual foundations: Analysing frameworks for ecosystem services and poverty alleviation research. *Global Environmental Change,* 23 (5), 1098-1111.

Foddy, W. (1993) *Constructing Questions for Interviews and Questionnaires.* Cambridge: Cambridge University Press.

Fontaine, L.C. and Larson, B.M.H. (2016) The Right Tree at the Right Place? Exploring Urban Foresters Perceptions of Assisted Migration. *Urban Forestry & Urban Greening,* 18, 221-227.

Foresight Land Use Futures Project (2010) *Land Use Futures: Making the most of land in the 21st century. Final Project Report.* London: Government Office for Science. Available from: http://webarchive.nationalarchives.gov.uk/+/http://www.bis.gov.uk/foresight/our-work/projects/current-projects/land-use-futures.

Forest Service (2006) *Northern Ireland Forestry: A Strategy for Sustainability and Growth*. Belfast, UK: DARDNI. Available from: https://www.daera-ni.gov.uk/sites/default/files/publications/dard/strategy-for-sustainability-growth.pdf.

Forestry Commission (2011) *National Forest Inventory outputs* Available from: http://www.forestry.gov.uk/forestry/infd-8eyjwf [Accessed 12th January 2016].

Forestry Commission Scotland (2010) *The right tree in the right place: Planning for forestry and woodlands*. Edinburgh: Forestry Commission Scotland.

Forestry Commission Working Group (2013) *The Barriers and Drivers to Planting and Retaining Urban Trees: Working Draft for Discussion* Available from: http://www.tdag.org.uk/uploads/4/2/8/0/4280686/btp_barriers_and_drivers_final_report_march_2013.pdf.

Foster, J., Lowe, A. and Winkelman, S. (2011) *The value of green infrastructure for urban climate adaptation*. Washington DC: The Centre for Clean Air Policy.

Franklin, J. (2016) Southampton shamed again for high levels of air pollution by WHO. *Daily Echo*, 12th May 2016. Available from: https://www.dailyecho.co.uk/news/14488027.southampton-shamed-again-for-high-levels-of-air-pollution-by-who/.

Frantzeskaki, N. (2019) Seven lessons for planning nature-based solutions in cities. *Environmental Science & Policy,* 93, 101-111.

Frith, H. and Gleeson, K. (2004) Clothing and Embodiment: Men Managing Body Image and Appearance. *Psychology of Men and Masculinity,* 5 (1), 40-48.

Gatto, P., Vidale, E., Secco, L. and Pettenella, D. (2014) Exploring the willingness to pay for forest ecosystem services by residents of the Veneto Region. *Bio-based and Applied Economics,* 3 (1), 21-43.

Geneletti, D. and Zardo, L. (2016) Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans. *Land Use Policy,* 50, 38-47.

Giergiczny, M. and Kronenberg, J. (2014) From valuation to governance: using choice experiment to value street trees. *Ambio,* 43 (4), 492-501.

Gilchrist, K., Brown, C. and Montarzino, A. (2015) Workplace settings and wellbeing: Greenspace use and views contribute to employee wellbeing at peri-urban business sites. *Landscape and Urban Planning,* 138, 32-40.

Gill, S.E., Handley, J.F., Ennos, A.R. and Pauleit, S. (2007) Adapting Cities for Climate Change: The Role of the Green Infrastructure. *Built Environment,* 33 (1), 115-133.

Glenk, K. and Colombo, S. (2011) How Sure Can You Be? A Framework for Considering Delivery Uncertainty in Benefit Assessments Based on Stated Preference Methods. *Journal of Agricultural Economics,* 62 (1), 25-46.

Glenk, K. and Colombo, S. (2013) Modelling outcome-related risk in choice experiments. *Australian Journal of Agricultural and Resource Economics,* 57 (4), 559-578.

Glenk, K., Schaafsma, M., Moxey, A., Martin-Ortega, J. and Hanley, N. (2014) A framework for valuing spatially targeted peatland restoration. *Ecosystem Services,* 9, 20-33.

Gneezy, U. and Potters, J. (1997) An experiment on risk taking and evaluation periods. *Quarterly Journal of Economics,* 112 (2), 631-645.

Gómez-Baggethun, E. and Barton, D.N. (2013) Classifying and valuing ecosystem services for urban planning. *Ecological Economics,* 86, 235-245.

Gómez-Baggethun, E. and Muradian, R. (2015) In markets we trust? Setting the boundaries of Market-Based Instruments in ecosystem services governance. *Ecological Economics,* 117, 217-224.

Goodpaster, K.E. (2007) *Conscience and Corporate Culture*. MA: Blackwell Publishing.

Gore, T., Ozdemiroglu, E., Eadson, W., Gianferrara, E. and Phang, Z. (2013) *Green Infrastructure's contribution to economic growth: a review. A Final Report for Defra and Natural England*. London, UK: Eftec.

Graça, M., Queirós, C., Farinha-Marques, P. and Cunha, M. (2018) Street trees as cultural elements in the city: Understanding how perception affects ecosystem services management in Porto, Portugal. *Urban Forestry & Urban Greening,* 30, 194-205.

Grădinaru, S.R. and Hersperger, A.M. (2018) Green infrastructure in strategic spatial plans: Evidence from European urban regions. *Urban Forestry & Urban Greening*.

Greater Manchester Environment Team (2014) *Greater Manchester Ecosystem Services Pinch Points Study*. Manchester: Greater Manchester Combined Authority.

Greene, W.H. and Hensher, D.A. (2003) A latent class model for discrete choice analysis: contrasts with mixed logit. *Transportation Research Part B: Methodological,* 37 (8), 681-698.

Grima, N., Singh, S.J., Smetschka, B. and Ringhofer, L. (2016) Payment for Ecosystem Services (PES) in Latin America: Analysing the performance of 40 case studies. *Ecosystem Services,* 17, 24-32.

Guerry, A.D., Polasky, S., Lubchenco, J., Chaplin-Kramer, R., Daily, G.C., Griffin, R., Ruckelshaus, M., Bateman, I.J., Duraiappah, A., Elmqvist, T., Feldman, M.W., Folke, C., Hoekstra, J., Kareiva, P.M., Keeler, B.L., Li, S., Mckenzie, E., Ouyang, Z., Reyers, B., Ricketts, T.H., Rockstrom, J., Tallis, H. and Vira, B. (2015) Natural capital and ecosystem services informing decisions: From promise to practice. *Proceedings of the National Academy of Sciences,* 112 (24), 7348-7355.

Guest, G.S., Macqueen, K.M. and Namey, E.E. (2012) *Applied Thematic Analysis*. USA: SAGE Publications.

Haaland, C. and Van Den Bosch, C.K. (2015) Challenges and strategies for urban green-space planning in cities undergoing densification: A review. *Urban Forestry & Urban Greening,* 14 (4), 760-771.

Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgstrom, S., Breuste, J., Gomez-Baggethun, E., Gren, A., Hamstead, Z., Hansen, R., Kabisch, N., Kremer, P., Langemeyer, J., Rall, E.L., Mcphearson, T., Pauleit, S., Qureshi, S., Schwarz, N., Voigt, A., Wurster, D. and Elmqvist, T. (2014) A quantitative review of urban ecosystem service assessments: concepts, models, and implementation. *Ambio,* 43 (4), 413-433.

Haber, M. (1980) A Comparison of Some Continuity Corrections for the Chi-Squared Test on 2 × 2 Tables. *Journal of the American Statistical Association,* 75 (371), 510-515.

Haines-Young, R. and Potschin, M. (2018) *Common International Classification of Ecosystem Services (CICES) V5.1: Guidance on the Application of the Revised Structure*. Nottingham: Fabis Consulting Ltd.

Hajat, S., Vardoulakis, S., Heaviside, C. and Eggen, B. (2014) Climate change effects on human health: projections of temperature-related mortality for the UK during the 2020s, 2050s and 2080s. *Journal of Epidemiology and Community Health,* 68 (7), 641-648.

Hall, C., O'brien, L., Hand, K. and Raum, S. (2018) *Evaluation of i-Tree Eco surveys in Great Britain. Impacts and key lessons: The views of stakeholders*. Farnham: Forest Research. Available from: https://www.researchgate.net/publication/324224060_Evaluation_of_i-Tree_Eco_surveys_in_Great_Britain_Impacts_and_key_lessons_The_views_of_stakeholders.

Halstead, J.M., Luloff, A.E. and Stevens, T.H. (2017) Protest Bidders in Contingent Valuation. *Northeastern Journal of Agricultural and Resource Economics,* 21 (2), 160-169.

Hamel, P. and Bryant, B.P. (2017) Uncertainty assessment in ecosystem services analyses: Seven challenges and practical responses. *Ecosystem Services,* 24, 1-15.

Hampshire Chronicle (2018) City doctor urging people to help keep each other safe as heatwave looks set to continue. *Hampshire Chronicle*. Available from: https://www.hampshirechronicle.co.uk/news/16369370.city-doctor-urging-people-to-help-keep-each-other-safe-as-heatwave-looks-set-to-continue/.

Hamrick, K. and Goldstein, A. (2016) *Raising Ambition: State of the Voluntary Carbon Markets 2016*. Washington DC: Ecosystem Marketplace. Available from: http://www.forest-trends.org/documents/files/doc_5242.pdf.

Handley, J.F. and Gill, S.E. (2009) Woodlands helping society to adapt IN: Read, D.J., Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, C.C. and Snowdon, P. (eds.) *Combating climate change – A role for UK forests*. Edinburgh: The Stationery Office, 180-194.

Hanley, N., Boyce, C., Czajkowski, M., Tucker, S., Noussair, C. and Townsend, M. (2016a) Sad or Happy? The Effects of Emotions on Stated Preferences for Environmental Goods. *Environmental and Resource Economics*.

Hanley, N., Kuhfuss, L., Préget, R. and Thoyer, S. (2016b) Nudging farmers to enrol land into agri-environmental schemes: the role of a collective bonus. *European Review of Agricultural Economics,* 43 (4), 609-636.

Hanley, N., Mourato, S. and Wright, R.E. (2001) Choice Modelling Approaches: A Superior Alternative for Environmental Valuation. *Journal of Economic Surveys,* 15, 435–462.

Hansen, R., Frantzeskaki, N., Mcphearson, T., Rall, E., Kabisch, N., Kaczorowska, A., Kain, J.H., Artmann, M. and Pauleit, S. (2015) The uptake of the ecosystem services concept in planning discourses of European and American cities. *Ecosystem Services,* 12, 228-246.

Hansen, R., Olafsson, A.S., Van Der Jagt, A.P.N., Rall, E. and Pauleit, S. (2019) Planning multifunctional green infrastructure for compact cities: What is the state of practice? *Ecological Indicators,* 96 (2), 99-110.

Hansen, R. and Pauleit, S. (2014) From Multifunctionality to Multiple Ecosystem Services? A Conceptual Framework for Multifunctionality in Green Infrastructure Planning for Urban Areas. *AMBIO,* 43 (4), 516-529.

Hansen, R., Rolf, W., Santos, A., Luz, A.C., Száraz, L., Tosics, I., Vierikko, K., Rall, E., Davies, C. and Pauleit, S. (2016) *Advanced Urban Green Infrastructure Planning and Implementation - Innovative Approaches and Strategies from European Cities*. Greensurge.

Hattam, C., Böhnke-Henrichs, A., Börger, T., Burdon, D., Hadjimichael, M., Delaney, A., Atkins, J.P., Garrard, S. and Austen, M.C. (2015) Integrating methods for ecosystem service assessment and valuation: Mixed methods or mixed messages? *Ecological Economics,* 120, 126-138.

Hauck, J., Schweppe-Kraft, B., Albert, C., Gorg, C., Jax, K., Jensen, R., Furst, C., Maes, J., Ring, I., Honigova, I., Burkhard, B., Mehring, M., Tiefenbach, M., Grunewald, K., Schwarzer, M., Meurer, J., Sommerhauser, M., Priess, J.A., Schmidt, J. and Gret-Regamey, A. (2013) The Promise of the Ecosystem Services Concept for Planning and Decision-Making. *Gaia-Ecological Perspectives for Science and Society,* 22 (4), 232-236.

Hauer, R.J. and Peterson, W.D. (2016) *Municipal Tree Care and Management in the United States: A 2014 Urban & Community Forestry Census of Tree Activities*. Wisconsin, USA: University of Wisconsin.

Hausknost, D., Grima, N. and Singh, S.J. (2017) The political dimensions of Payments for Ecosystem Services (PES): Cascade or stairway? *Ecological Economics,* 131, 109-118.

Hausman, D.M. (2011) *Preference, Value, Choice, and Welfare*. Cambridge: Cambridge University Press.

Hejnowicz, A.P., Raffaelli, D.G., Rudd, M.A. and White, P.C.L. (2014) Evaluating the outcomes of payments for ecosystem services programmes using a capital asset framework. *Ecosystem Services,* 9, 83-97.

Hensher, D.A. (2010) Hypothetical bias, choice experiments and willingness to pay. *Transportation Research Part B: Methodological,* 44 (6), 735-752.

Hensher, D.A. and Greene, W.H. (2003) The Mixed Logit model: The state of practice. *Transportation,* 30 (2), 133-176.

Hensher, D.A., Rose, J.M. and Greene, W.H. (2005) *Applied choice analysis: A primer.* Cambridge: Cambridge University Press.

Hess, S. (2010) Conditional parameter estimates from Mixed Logit models: distributional assumptions and a free software tool. *Journal of Choice Modelling,* 3 (2), 134-152.

Hess, S. and Beharry-Borg, N. (2012) Accounting for Latent Attitudes in Willingness-to-Pay Studies: The Case of Coastal Water Quality Improvements in Tobago. *Environmental and Resource Economics,* 52 (1), 109-131.

Hess, S., Erath, A. and Axhausen, K. (2008) Estimated Value of Savings in Travel Time in Switzerland: Analysis of Pooled Data. *Transportation Research Record: Journal of the Transportation Research Board,* 2082, 43-55.

Hess, S. and Rose, J.M. (2012) Can scale and coefficient heterogeneity be separated in random coefficients models? *Transportation,* 39 (6), 1225-1239.

Hess, S. and Train, K. (2017) Correlation and scale in mixed logit models. *Journal of Choice Modelling,* 23, 1-8.

Hicks, J. (1939) *Value and Capital*. Oxford, UK: Clarendon Press.

Hirschman, A.O. (1965) Obstacles to Development: A Classification and a Quasi-Vanishing Act. *Economic Development and Cultural Change,* 13 (4, Part 1), 385-393.

Hm Treasury (2018) *Policy paper: Budget 2018*. London: HM Treasury,. Available from: https://www.gov.uk/government/publications/budget-2018-documents/budget-2018#supporting-public-services-and-people.

Holmes, T.P., Adamowicz, W.L. and Carlsson, F. (2017) Choice Experiments IN: Champ, P., A., Boyle, K.J. and Brown, T., C. (eds.) *A Primer on Nonmarket Valuation*, 2nd ed. Dordrecht, The Netherlands: Springer, 133-186.

Hölzinger, O. and Grayson, N. (2019) *Birmingham Health Economic Assessment & Natural Capital Accounts: Revealing the True Value of Council-managed Parks and Greenspaces*. Birmingham: Birmingham City Council.

Hubacek, K. and Kronenberg, J. (2013) Synthesizing different perspectives on the value of urban ecosystem services. *Landscape and Urban Planning,* 109 (1), 1-6.

Huffman, W.E., Rousu, M., Shogren, J.F. and Tegene, A. (2007) The effects of prior beliefs and learning on consumers' acceptance of genetically modified foods. *Journal of Economic Behavior & Organization,* 63 (1), 193-206.

Ibm (2016) SPSS Statistics 24 ed. New York, USA: IBM Corporation. Available from: https://www.ibm.com/support/knowledgecenter/SSLVMB_24.0.0/spss/product_landing.html.

Iftekhar, M.S., Polyakov, M., Ansell, D., Gibson, F. and Kay, G.M. (2017) How economics can further the success of ecological restoration. *Conservation Biology,* 31 (2), 261-268.

Igoe, J. (2013) Consume, connect, conserve: Consumer spectacle and the technical mediation of neoliberal conservation's aesthetic of redemption and repair. *Human Geography,* 6 (1), 16-28.

Inflationdata.Com (2019) *Historical Consumer Price Index (CPI-U) Data*. Available from: https://inflationdata.com/Inflation/Consumer_Price_Index/HistoricalCPI.aspx?reloaded=true [Accessed 31/03/2019].

Innes, D. and Tetlow, G. (2015) *Central Cuts, Local Decision-Making: Changes in Local Government Spending and Revenues in England, 2009-10 to 2014-15*. London: The Institute for Fiscal Studies.

Ipbes (2015) *Preliminary guide regarding diverse conceptualization of multiple values of nature and its benefits, including biodiversity and ecosystem functions and services (deliverable 3(d)). IPBES/4/INF/13*. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Available from: http://www.ipbes.net/sites/default/files/downloads/IPBES-4-INF-13_EN.pdf.

Ipcc (2014) *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)].* . Geneva, Switzerland: Ipcc.

Iucn (2015) *UK Peatland Code 1.0*. Flintshire, UK: Iucn Uk National Committee.

Jack, B.K., Kousky, C. and Sims, K.R. (2008) Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms. *Proceedings of the National Academy of Sciences,* 105 (28), 9465-9470.

Jacobs, S., Dendoncker, N., Martín-López, B., Barton, D.N., Gomez-Baggethun, E., Boeraeve, F., Mcgrath, F.L., Vierikko, K., Geneletti, D., Sevecke, Katharina j., Pipart, N., Primmer, E., Mederly, P., Schmidt, S., Aragão, A., Baral, H., Bark, Rosalind h., Briceno, T., Brogna, D., Cabral, P., De Vreese, R., Liquete, C., Mueller, H., Peh, K.S.H., Phelan, A., Rincón, Alexander r., Rogers, S.H., Turkelboom, F., Van Reeth, W., Van Zanten, B.T., Wam, H.K. and Washbourn, C.-L. (2016) A new valuation school: Integrating diverse values of nature in resource and land use decisions. *Ecosystem Services,* 22, 213-220.

Jacobs, S., Martin-Lopez, B., Barton, D.N., Dunford, R., Harrison, P.A., Kelemen, E., Saarikoski, H., Termansen, M., Garcia-Llorente, M., Gomez-Baggethun, E., Kopperoinen, L., Luque, S., Palomo, I., Priess, J.A., Rusch, G.M., Tenerelli, P., Turkelboom, F., Demeyer, R., Hauck, J., Keune, H. and Smith, R. (2018) The means determine the end - Pursuing integrated valuation in practice. *Ecosystem Services,* 29, 515-528.

Jakus, P.M. and Shaw, W.D. (2003) Perceived Hazard and Product Choice: An Application to Recreational Site Choice. *Journal of Risk and Uncertainty,* 26 (1), 77-92.

Janssen, M.A. and Ostrom, E. (2006) Chapter 30 Governing Social-Ecological Systems IN: Tesfatsion, L. and Judd, K.L. (eds.) *Handbook of Computational Economics*. Elsevier, 1465-1509.

Japelj, A., Mavsar, R., Hodges, D., Kovač, M. and Juvančič, L. (2016) Latent preferences of residents regarding an urban forest recreation setting in Ljubljana, Slovenia. *Forest Policy and Economics,* 71, 71-79.

Jaszczak, R. and Wajchman, S. (2015) Selected aspects of forest management in the urban forests of the city of Poznań and the State Forests in Poland. *Sylwan,* 159 (2), 160-167.

Jetter, K. and Paine, T.D. (2004) Consumer preferences and willingness to pay for biological control in the urban landscape. *Biological Control,* 30 (2), 312-322.

Johnson, F.R., Lancsar, E., Marshall, D., Kilambi, V., Muhlbacher, A., Regier, D.A., Bresnahan, B.W., Kanninen, B. and Bridges, J.F. (2013) Constructing experimental designs for discrete-choice experiments: report of the ISPOR Conjoint Analysis Experimental Design Good Research Practices Task Force. *Value Health,* 16 (1), 3-13.

Johnston, M. (1995) The Forest of Belfast: Healing the Environment and the Community. *Arboricultural Journal,* 19 (1), 53-72.

Johnston, R.J., Boyle, K.J., Adamowicz, W., Bennett, J., Brouwer, R., Cameron, T.A., Hanemann, W.M., Hanley, N., Ryan, M., Scarpa, R., Tourangeau, R. and Vossler, C.A. (2017) Contemporary Guidance for Stated Preference Studies. *Journal of the Association of Environmental and Resource Economists,* 4 (2), 319-405.

Jorgensen, E. (1986) Urban forestry in the rearview mirror. *Arboricultural Journal,* 10 (3), 177-190.

Juntti, M. and Lundy, L. (2017) A mixed methods approach to urban ecosystem services: Experienced environmental quality and its role in ecosystem assessment within an inner-city estate. *Landscape and Urban Planning,* 161, 10-21.

Kabisch, N. (2015) Ecosystem service implementation and governance challenges in urban green space planning—The case of Berlin, Germany. *Land Use Policy,* 42, 557-567.

Kabisch, N., Korn, H., Stadler, J. and Bonn, A. (2017) Nature-Based Solutions to Climate Change Adaptation in Urban Areas - Linkages Between Science, Policy and Practice IN: Kabisch, N., Korn, H., Stadler, J. and Bonn, A. (eds.) *Nature-based Solutions to Climate Change Adaptation in Urban Areas*. Cham, Switzerland: Springer Open, 1-11.

Kahneman, D. and Tversky, A. (1979) Prospect Theory: An Analysis of Decision Under Risk. *Econometrica,* 47, 263-291.

Kallis, G., Gómez-Baggethun, E. and Zografos, C. (2013) To value or not to value? That is not the question. *Ecological Economics,* 94, 97-105.

Kanninen, B.J. (2006) *Valuing Environmental Amenities Using Stated Choice Studies: A Common Sense Approach to Theory and Practice*. Arlington, Virginia, USA: Springer.

Kaplan, R. (1993) The role of nature in the workplace. *Landscape and Urban Planning,* 26, 193-201.

Kardash, C.M. and Scholes, R.J. (1996) Effects of preexisiting beliefs, epistemological beliefs, and need for cognition on interpretation of controversial issues. *Journal of Educational Psychology,* 88 (2), 260-271.

Kemkes, R.J., Farley, J. and Koliba, C.J. (2010) Determining when payments are an effective policy approach to ecosystem service provision. *Ecological Economics,* 69 (11), 2069-2074.

Kenney, W.A., Van Wassenaer, P.J.E. and Satel, A.L. (2011) Criteria and Indicators for Strategic Urban Forest Planning and Management. *Arboriculture & Urban Forestry,* 37 (3), 108-117.

Kirkpatrick, J.B., Davison, A. and Daniels, G.D. (2012) Resident attitudes towards trees influence the planting and removal of different types of trees in eastern Australian cities. *Landscape and Urban Planning,* 107 (2), 147-158.

Klöckner, C.A. (2013) A comprehensive model of the psychology of environmental behaviour—A meta-analysis. *Global Environmental Change,* 23 (5), 1028-1038.

Knight, F.H. (1921) *Risk, Uncertainty, and Profit*. Available from: http://www.econlib.org/library/Knight/knRUP.html [Accessed 27th November 2017].

Knol, D.L. and Berger, M.P.F. (1991) Empirical Comparison Between Factor Analysis and Multidimensional Item Response Models. *Multivariate Behavioral Research,* 26 (3), 457-477.

Koellner, T., Sell, J. and Navarro, G. (2010) Why and how much are firms willing to invest in ecosystem services from tropical forests? A comparison of international and Costa Rican firms. *Ecological Economics,* 69 (11), 2127-2139.

Kohlberg, L. (1981) *The philosophy of moral development: Moral stages and the idea of justice.* New York, USA: Harper & Row.

Konijnendijk, C.C. (2003) A decade of urban forestry in Europe. *Forest Policy and Economics,* 5 (2), 173-186.

Kosoy, N. and Corbera, E. (2010) Payments for ecosystem services as commodity fetishism. *Ecological Economics,* 69 (6), 1228-1236.

Kragt, M.E., Gibson, F.L., Maseyk, F. and Wilson, K.A. (2016) Public willingness to pay for carbon farming and its co-benefits. *Ecological Economics,* 126, 125-131.

Krause, M.S. and Matzdorf, B. (2019) The intention of companies to invest in biodiversity and ecosystem services credits through an online-marketplace. *Ecosystem Services,* 40, 101026.

Kremer, P., Hamstead, Z., Haase, D., Mcphearson, T., Frantzeskaki, N., Andersson, E., Kabisch, N., Larondelle, N., Rall, E.L., Voigt, A., Baró, F., Bertram, C., Gómez-Baggethun, E., Hansen, R., Kaczorowska, A., Kain, J.-H., Kronenberg, J., Langemeyer, J., Pauleit, S., Rehdanz, K., Schewenius, M., Van Ham, C., Wurster, D. and Elmqvist, T. (2016) Key insights for the future of urban ecosystem services research. *Ecology and Society,* 21 (2), 29.

Krinsky, I. and Robb, A. (1986) On Approximating the Statistical Properties of Elasticities. *The Review of Economics and Statistics,* 68 (4), 715-719.

Kroeger, T. (2013) The quest for the "optimal" payment for environmental services program: Ambition meets reality, with useful lessons. *Forest Policy and Economics,* 37, 65-74.

Lafortezza, R. and Chen, J. (2016) The provision of ecosystem services in response to global change: Evidences and applications. *Environmental Research,* 147, 576-579.

Lafortezza, R., Davies, C., Sanesi, G. and Konijnendijk, C.C. (2013) Green Infrastructure as a tool to support spatial planning in European urban regions. *iForest - Biogeosciences and Forestry,* 6 (2), 102-108.

Lafortezza, R. and Giannico, V. (2019) Combining high-resolution images and LiDAR data to model ecosystem services perception in compact urban systems. *Ecological Indicators,* 96, 87-98.

Laing, T., Taschini, L., Palmer, C., Wehkamp, J., Fuss, S. and Reuter, W.H. (2015) *Understanding the demand for REDD+ credits*. London and Leeds: Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment.

Lam, S.T. and Conway, T.M. (2018) Ecosystem services in urban land use planning policies: A case study of Ontario municipalities. *Land Use Policy,* 77, 641-651.

Lancaster, K. (1966) A New Approach to Consumer Theory. *Journal of Political Economy,* 74 (2), 132-157.

Lau, J.D., Hicks, C.C., Gurney, G.G. and Cinner, J.E. (2019) What matters to whom and why? Understanding the importance of coastal ecosystem services in developing coastal communities. *Ecosystem Services,* 35, 219-230.

Lawrence, A. (2017) Adapting through practice: Silviculture, innovation and forest governance for the age of extreme uncertainty. *Forest Policy and Economics,* 79, 50-60.

Leicester City Council (2018) *Leicester City Council Tree Strategy (Supporting document) 2018 - 2023* Leicester, UK: Leicester City Council. Available from: https://www.leicester.gov.uk/your-council/city-mayor-peter-soulsby/my-vision/tree-strategy/.

Lemonsu, A., Viguié, V., Daniel, M. and Masson, V. (2015) Vulnerability to heat waves: Impact of urban expansion scenarios on urban heat island and heat stress in Paris (France). *Urban Climate,* 14, 586-605.

Lennon, M., Scott, M., Collier, M. and Foley, K. (2017) The emergence of green infrastructure as promoting the centralisation of a landscape perspective in spatial planning—the case of Ireland. *Landscape Research,* 42 (2), 146-163.

Li, H. and Liu, Y. (2016) Neighborhood socioeconomic disadvantage and urban public green spaces availability: A localized modeling approach to inform land use policy. *Land Use Policy,* 57, 470-478.

Lima, L.S.D., Krueger, T. and García-Marquez, J. (2017) Uncertainties in demonstrating environmental benefits of payments for ecosystem services. *Ecosystem Services,* 27, 139-149.

Lo, A.Y., Byrne, J.A. and Jim, C.Y. (2017) How climate change perception is reshaping attitudes towards the functional benefits of urban greenery: Lessons from Hong Kong. *Urban Forestry & Urban Greening*.

Lo, A.Y. and Jim, C.Y. (2015) Protest response and willingness to pay for culturally significant urban trees: Implications for Contingent Valuation Method. *Ecological Economics,* 114, 58-66.

Lockie, S. (2013) Market instruments, ecosystem services, and property rights: Assumptions and conditions for sustained social and ecological benefits. *Land Use Policy,* 31, 90-98.

Lohr, V.I., Pearson-Mims, C.H., Tarnai, J. and Dilman, D.A. (2004) How urban residents rate and rank the benefits and problems associated with trees in cities. *Journal of Arboriculture,* 30 (1), 28-35.

Lord, C.G., Ross, L. and Lepper, M.R. (1979) Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence. *Journal of Personality and Social Psychology,* 37 (11), 2098-2109.

Lorenzo, A.B., Blanche, C.A., Qi, Y.D. and Guidry, M.M. (2000) Assessing residents' willingness to pay to preserve the community urban forest: a small-city case study. *Journal of Arboriculture,* 26 (6), 319-325.

Lottrup, L., Stigsdotter, U.K., Meilby, H. and Claudi, A.G. (2015) The Workplace Window View: A Determinant of Office Workers' Work Ability and Job Satisfaction. *Landscape Research,* 40 (1), 57-75.

Louviere, J.J., Hensher, D.A. and Swait, J.D. (2000) *Stated Choice Methods: Analysis and Applications*. Cambridge: Cambridge University Press.

Low, S. and Carney, T. (2012) Inter-Governmental Policy Implementation: State Inducements to Encourage Implementation at the Local Level. *International Journal of Public Administration,* 35 (3), 177-193.

Luederitz, C., Brink, E., Gralla, F., Hermelingmeier, V., Meyer, M., Niven, L., Panzer, L., Partelow, S., Rau, A.-L., Sasaki, R., Abson, D.J., Lang, D.J., Wamsler, C. and Von Wehrden, H. (2015) A review of urban ecosystem services: six key challenges for future research. *Ecosystem Services,* 14, 98-112.

Lundhede, T., Jacobsen, J.B., Hanley, N., Strange, N. and Thorsen, B.J. (2015) Incorporating Outcome Uncertainty and Prior Outcome Beliefs in Stated Preferences. *Land Economics,* 91 (2), 296-316.

Lundhede, T.H., Olsen, S.B., Jacobsen, J.B. and Thorsen, B.J. (2009) Handling respondent uncertainty in Choice Experiments: Evaluating recoding approaches against explicit modelling of uncertainty. *Journal of Choice Modelling,* 2 (2), 118-147.

Luzar, E.J. and Cosse, K.J. (1998) Willingness to pay or intention to pay: The attitude-behavior relationship in contingent valuation. *The Journal of Socio-Economics,* 27 (3), 427-444.

Lyytimäki, J. and Sipilä, M. (2009) Hopping on one leg – The challenge of ecosystem disservices for urban green management. *Urban Forestry & Urban Greening,* 8 (4), 309-315.

Mace, G.M., Bateman, I., Albon, S., Balmford, A., Brown, C., Church, A., Haines-Young, R., Pretty, J.N., Turner, K., Vira, B. and Winn, J. (2011) Chapter 2: Conceptual Framework and Methodology IN: Uk Nea (ed.) *UK National Ecosystem Assessment Technical Report*. Cambridge: UNEP-WCMC, 11-26.

Mace, G.M., Norris, K. and Fitter, A.H. (2012) Biodiversity and ecosystem services: a multilayered relationship. *Trends in Ecology & Evolution,* 27 (1), 19-26.

Macgillivray, A. and Wragg, S. (2013) *Payment for Ecosystem Services (PES) Pilot on Flood Regulation in Hull*. London: Ursus Consulting Ltd.

Madureira, H., Nunes, F., Oliveira, J.V., Cormier, L. and Madureira, T. (2015) Urban residents' beliefs concerning green space benefits in four cities in France and Portugal. *Urban Forestry & Urban Greening,* 14 (1), 56-64.

Manfreda, K.L., Bosnjak, M., Berzelak, J., Haas, I. and Vehovar, V. (2008) Web surveys versus other survey modes: A meta-analysis comparing response rates. *International Journal of Market Research,* 50 (1), 79-104.

Manski, C.F. (1977) The structure of random utility models. *Theory and Decision,* 8 (3), 229-254.

Mariel, P., Meyerhoff, J. and Hess, S. (2015) Heterogeneous preferences toward landscape externalities of wind turbines – combining choices and attitudes in a hybrid model. *Renewable and Sustainable Energy Reviews,* 41, 647-657.

Marta-Pedroso, C., Freitas, H. and Domingos, T. (2007) Testing for the survey mode effect on contingent valuation data quality: A case study of web based versus in-person interviews. *Ecological Economics,* 62 (3-4), 388-398.

Martín-López, B., Gómez-Baggethun, E., García-Llorente, M. and Montes, C. (2014) Trade-offs across value-domains in ecosystem services assessment. *Ecological Indicators,* 37, 220-228.

Martin-Ortega, J., Glenk, K. and Byg, A. (2017) How to make complexity look simple? Conveying ecosystems restoration complexity for socio-economic research and public engagement. *PLoS One,* 12 (7), e0181686.

Martin-Ortega, J., Jorda-Capdevila, D., Glenk, K. and Holstead, K.L. (2015) What defines ecosystem services-based approaches? IN: Gordon, I.J., Martin-Ortega, J., Ferrier, R.C. and Khan, S. (eds.) *Water Ecosystem Services: A Global Perspective*. Cambridge: Cambridge University Press, 3-14.

Martin-Ortega, J., Mesa-Jurado, M.A., Pineda-Vazquez, M. and Novo, P. (2019) Nature commodification: 'a necessary evil'? An analysis of the views of environmental professionals on ecosystem services-based approaches. *Ecosystem Services,* 37, 100926.

Martin-Ortega, J. and Waylen, K.A. (2018) PES What a Mess? An Analysis of the Position of Environmental Professionals in the Conceptual Debate on Payments for Ecosystem Services. *Ecological Economics,* 154, 218-237.

Matthews, T., Lo, A.Y. and Byrne, J.A. (2015) Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. *Landscape and Urban Planning,* 138, 155-163.

Matzdorf, B., Sattler, C. and Engel, S. (2013) Institutional frameworks and governance structures of PES schemes. *Forest Policy and Economics,* 37, 57-64.

Mcdermott, M., Mahanty, S. and Schreckenberg, K. (2013) Examining equity: A multidimensional framework for assessing equity in payments for ecosystem services. *Environmental Science & Policy,* 33, 416-427.

Mcfadden, D. (1968) *The Revealed Preferences of a Public Bureaucracy*. Berkeley, CA, USA: University of California.

Mcfadden, D. (1979) Quantitative Methods for Analyzing Travel Behaviour of Individuals: Some Recent Developments IN: Hensher, D. and Stopher, P. (eds.) *Behavioural Travel Modelling*. London: Croom Helm, 279-318.

Mcfadden, D. (1999) Rationality for Economists? *Journal of Risk and Uncertainty,* 19 (1-3), 73-105.

Mcfadden, D. and Train, K. (2000) Mixed MNL models for discrete response. *Journal of Applied Econometrics,* 15 (5), 447-470.

Mea (2005) *Millenium Ecosystem Assessment. Ecosystems and Human Well-being: Synthesis*. Washington DC: Island Press.

Mehta, L., Leach, M. and Scoones, I. (2001) Editorial: Environmental Governance in an Uncertain World. *IDS Bulletin,* 32 (4), 1-9.

Meißner, N. (2013) The incentives of private companies to invest in protected area certificates: How coalitions can improve ecosystem sustainability. *Ecological Economics,* 95, 148-158.

Meißner, N. and Grote, U. (2015) Motives, opportunities, and risks for private sector investment in protected areas with international importance: evidence from German companies. *Environment, Development and Sustainability*, 1-21.

Mell, I. (2016a) GI management – time to 'let someone else have a go'? *Town and Country Planning,* 85 (4-5), 138-141.

Mell, I. (2018) Financing the future of green infrastructure planning: alternatives and opportunities in the UK. *Landscape Research,* 43 (6), 751-768.

Mell, I.C. (2014) Aligning fragmented planning structures through a green infrastructure approach to urban development in the UK and USA. *Urban Forestry & Urban Greening,* 13 (4), 612-620.

Mell, I.C. (2016b) Financing Green Infrastructure in times of Austerity: The case of Liverpool, UK. *Biotope City Journal,* (Issue Unspecified).

Mell, I.C., Henneberry, J., Hehl-Lange, S. and Keskin, B. (2013) Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK. *Urban Forestry & Urban Greening,* 12 (3), 296-306.

Mell, I.C., Henneberry, J., Hehl-Lange, S. and Keskin, B. (2016) To green or not to green: Establishing the economic value of green infrastructure investments in The Wicker, Sheffield. *Urban Forestry & Urban Greening,* 18, 257-267.

Met Office (2018) *UK Climate Summaries* Available from: https://www.metoffice.gov.uk/climate/uk/summaries [Accessed 15th January 2019].

Meyer, M.A. and Schulz, C. (2017) Do ecosystem services provide an added value compared to existing forest planning approaches in Central Europe? *Ecology and Society,* 22 (3).

Miller, J.D. and Hutchins, M. (2017) The impacts of urbanisation and climate change on urban flooding and urban water quality: A review of the evidence concerning the United Kingdom. *Journal of Hydrology: Regional Studies,* 12, 345-362.

Miller, R.W. (1997) *Urban Forestry: Planning and Managing Urban Greenspaces*, 2nd ed. New York: Prentice-Hall.

Moffat, A.J. (2016) Communicating the benefits of urban trees: A critical review. *Arboricultural Journal,* 38 (2), 1-19.

Moore, M. (2008) Global justice, climate change and Miller's theory of responsibility. *Critical Review of International Social and Political Philosophy,* 11 (4), 501-517.

Morawetz, U.B. and Koemle, D.B.A. (2017) Contingent Valuation of Measures against Urban Heat: Limitations of a Frequently Used Method. *Journal of Urban Planning and Development,* 0 (0).

Morgenroth, J., Östberg, J., Konijnendijk Van Den Bosch, C., Nielsen, A.B., Hauer, R., Sjöman, H., Chen, W. and Jansson, M. (2016) Urban tree diversity—Taking stock and looking ahead. *Urban Forestry & Urban Greening,* 15, 1-5.

Mouchet, M.A., Lamarque, P., Martín-López, B., Crouzat, E., Gos, P., Byczek, C. and Lavorel, S. (2014) An interdisciplinary methodological guide for quantifying associations between ecosystem services. *Global Environmental Change,* 28, 298-308.

Muñoz-Piña, C., Guevara, A., Torres, J.M. and Braña, J. (2008) Paying for the hydrological services of Mexico's forests: Analysis, negotiations and results. *Ecological Economics,* 65 (4), 725-736.

Muradian, R., Corbera, E., Pascual, U., Kosoy, N. and May, P.H. (2010) Reconciling theory and practice: An alternative conceptual framework for understanding payments for environmental services. *Ecological Economics,* 69 (6), 1202-1208.

Mutch, E.M., Doick, K.J., Davies, H.J., Handley, P., Hudson, M.D., Kiss, S., Mcculloch, L., Parks, K.E., Rogers, K. and Schreckenberg, K. (2017) *The value of Southampton's urban trees. Results of the 2016 i-Tree Eco survey*. Southampton, UK: University of Southampton, Forest Research, Treeconomics and Southampton City Council.

Nakagawa, S. (2004) A farewell to Bonferroni: the problems of low statistical power and publication bias. *Behavioral Ecology,* 15 (6), 1044-1045.

Narloch, U., Pascual, U. and Drucker, A.G. (2013) How to achieve fairness in payments for ecosystem services? Insights from agrobiodiversity conservation auctions. *Land Use Policy,* 35, 107-118.

National Audit Office (2014) *The impact of funding reductions on local authorities*. London: National Audit Office.

Natural Capital Coalition (n.d.) *Natural Capital Protocol* Available from: https://naturalcapitalcoalition.org/natural-capital-protocol/.

Natural Capital Committee (2015) *The State of Natural Capital: Protecting and improving natural capital for prosperity and wellbeing. Third report to the Economic Affairs Committee*. Natural Capital Committee.

Natural Resources Wales (2014) *Tree Cover in Wales' Towns and Cities: Understanding canopy cover to better plan and manage our urban trees.* Aberystwyth: Natural Resources Wales,.

Nature Greater Manchester (2019) *Urban Pioneer*. Available from: https://naturegreatermanchester.co.uk/project/urban-pioneer/ [Accessed 23rd January 2019].

Naturevest (2017) *Washington D.C. Green Infrastructure Fund*. Available from: http://www.naturevesttnc.org/business-lines/green-infrastructure/dc-green-infrastructure/ [Accessed 13th October 2017].

Naumann, S., Anzaldua, G., Berry, P., Burch, S., Davis, M., Frelih-Larsen, A., Gerdes, H. and Sanders, M. (2011) *Assessment of the potential of ecosystem-based approaches to climate change adaptation and mitigation in Europe. Final report to the European Commission, DG Environment, Contract no. 070307/2010/580412/SER/B2*. Oxford University Centre for the Environment.

Needham, K., Czajkowski, M., Hanley, N. and Lariviere, J. (2018) What is the causal impact of information and knowledge in stated preference studies? *Resource and Energy Economics,* 54, 69-89.

Netcen (2006) *Air Quality and Social Deprivation in the UK: an environmental inequalities analysis - Final Report to Defra, Contract RMP/2035.* Didcot, Oxon: Netcen.

Ng, W.-Y., Chau, C.-K., Powell, G. and Leung, T.-M. (2015) Preferences for street configuration and street tree planting in urban Hong Kong. *Urban Forestry & Urban Greening,* 14 (1), 30-38.

Nguyen, T.N., Jakus, P.M., Riddel, M. and Shaw, W.D. (2010) An Empirical Model of Perceived Mortality Risks for Selected U.S. Arsenic Hot Spots. *Risk Analysis,* 30 (10), 1550-1562.

Nielsen, A.B., Konijnendijk, C.C., Wiström, B. and Jensen, R.B. (2013) Municipal woodland in Denmark: resources, governance and management. *Scandinavian Journal of Forest Research,* 28 (1), 49-63.

Nomis (2015) *Labour Market Profile - Southampton: Employee Jobs By Industry*. Available from: http://www.nomisweb.co.uk/reports/lmp/la/1946157287/report.aspx?town=southampton#tabjobs [Accessed 24 April 2017].

Nomis (2016) *Labour Market Profile - Southampton: UK Business Counts*. Available from: http://www.nomisweb.co.uk/reports/lmp/la/1946157287/report.aspx?town=southampton#tabidbr [Accessed 28 September 2017].

Nordin, A.C., Hanson, H.I. and Olsson, J.A. (2017) Integration of the ecosystem services concept in planning documents from six municipalities in southwestern Sweden. *Ecology and Society,* 22 (3), 18.

Nottingham City Council (2013) *Urban Forest Strategy 2012 to 2020*. Nottingham, UK: Nottingham City Council. Available from: http://www.nottinghamcity.gov.uk/trees.

Nowak, D.J. and Greenfield, E.J. (2018) Declining Urban and Community Tree Cover in the United States. *Urban Forestry & Urban Greening*.

Nyborg, K. (2000) Homo Economicus and Homo Politicus: interpretation and aggregation of environmental values. *Journal of Economic Behavior & Organization,* 42 (3), 305-322.

O'brien, L., Williams, K. and Stewart, A. (2010) *Urban health and health inequalities and the role of urban forestry in Britain: A review*. Farnham, Surrey: Forest Research.

Obeng, E.A. and Aguilar, F.X. (2018) Value orientation and payment for ecosystem services: Perceived detrimental consequences lead to willingness-to-pay for ecosystem services. *Journal of Environmental Management,* 206, 458-471.

Oecd.Stat (2019) *PPPs for GDP, for private consumption and for actual individual consumption, long time series for OECD Countries* Available from: http://stats.oecd.org/Index.aspx?datasetcode=SNA_TABLE4# [Accessed 31/03/2019].

Oehlert, G.W. (1992) A Note on the Delta Method. *The American Statistician,* 46 (1), 27-29.

Office for National Statistics (2009) *UK Standard Industrial Classification of Economic Activities 2007 (SIC 2007)*. Basingstoke, UK: Palgrave Macmillan.

Ojea, E. (2015) Challenges for mainstreaming Ecosystem-based Adaptation into the international climate agenda. *Current Opinion in Environmental Sustainability,* 14, 41-48.

Ojea, E., Martin-Ortega, J. and Chiabai, A. (2012) Defining and classifying ecosystem services for economic valuation: the case of forest water services. *Environmental Science & Policy,* 19-20, 1-15.

Ola, O., Menapace, L., Benjamin, E. and Lang, H. (2019) Determinants of the environmental conservation and poverty alleviation objectives of Payments for Ecosystem Services (PES) programs. *Ecosystem Services,* 35, 52-66.

Ons (2005) *Rural and Urban Area Classification 2004*. Available from: http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/guide-method/census/census-2001/data-and-products/data-and-product-catalogue/local-statistics/key-statistics-for-the-rural-and-urban-claassification-2004/index.html [Accessed 13th March 2016].

Ordóñez Barona, C. (2015) Research article: Adopting public values and climate change adaptation strategies in urban forest management: A review and analysis of the relevant literature. *Journal of Environmental Management,* 164, 215-221.

Ordóñez, C., Beckley, T., Duinker, P.N. and Sinclair, A.J. (2017) Public values associated with urban forests: Synthesis of findings and lessons learned from emerging methods and cross-cultural case studies. *Urban Forestry & Urban Greening,* 25, 74-84.

Ordóñez, C. and Duinker, P.N. (2013) An analysis of urban forest management plans in Canada: Implications for urban forest management. *Landscape and Urban Planning,* 116, 36-47.

Osborne, P. (2016) *Summer Land Surface Temperatures for Southampton UK (2006-2008)*. University of Southampton: Unpublished dataset.

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., Watson, R.T., Başak Dessane, E., Islar, M., Kelemen, E., Maris, V., Quaas, M., Subramanian, S.M., Wittmer, H., Adlan, A., Ahn, S., Al-Hafedh, Y.S., Amankwah, E., Asah, S.T., Berry, P., Bilgin, A., Breslow, S.J., Bullock, C., Cáceres, D., Daly-Hassen, H., Figueroa, E., Golden, C.D., Gómez-Baggethun, E., González-Jiménez, D., Houdet, J., Keune, H., Kumar, R., Ma, K., May, P.H., Mead, A., O'farrell, P., Pandit, R., Pengue, W., Pichis-Madruga, R., Popa, F., Preston, S., Pacheco-Balanza, D., Saarikoski, H., Strassburg, B.B., Van Den Belt, M., Verma, M., Wickson, F. and Yagi, N. (2017) Valuing nature's contributions to people: the IPBES approach. *Current Opinion in Environmental Sustainability,* 26-27, 7-16.

Pascual, U., Phelps, J., Garmendia, E., Brown, K., Corbera, E., Martin, A., Gomez-Baggethun, E. and Muradian, R. (2014) Social Equity Matters in Payments for Ecosystem Services. *BioScience,* 64 (11), 1027-1036.

Pattenden, S., Armstrong, B., Milojevic, A., Heal, M.R., Chalabi, Z., Doherty, R., Barratt, B., Kovats, R.S. and Wilkinson, P. (2010) Ozone, heat and mortality: acute effects in 15 British conurbations. *Occupational and Environmental Medicine,* 67 (10), 699-707.

Pauleit, S., Ennos, R. and Golding, Y. (2005) Modeling the environmental impacts of urban land use and land cover change—a study in Merseyside, UK. *Landscape and Urban Planning,* 71 (2-4), 295-310.

Pauleit, S., Jones, N., Garcia-Martin, G., Garcia-Valdecantos, J.L., Rivière, L.M., Vidal-Beaudet, L., Bodson, M. and Randrup, T.B. (2002) Tree establishment practice in towns and cities – Results from a European survey. *Urban Forestry & Urban Greening,* 1 (2), 83-96.

Pearce, D., Ozdemiroglu, E., Bateman, I., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Sugden, R. and Swanson, J. (2002) *Economic valuation with stated preference techniques*. London: Queen's Printer and Controller of HerMajesty's Stationery Office.

Pearce, D.W. (2001) The Economic Value of Forest Ecosystems. *Ecosystem Health,* 7 (4), 284-296.

Perrot-Maître, D. (2006) *The Vittel payments for ecosystem services: a "perfect" PES case?* London, UK: International Institute for Environment and Development. Available from: http://pubs.iied.org/pdfs/G00388.pdf.

Piccolo, J.J. (2017) Intrinsic values in nature: Objective good or simply half of an unhelpful dichotomy? *Journal for Nature Conservation,* 37, 8-11.

Poe, G.L., Giraud, K.L. and Loomis, J.B. (2005) Computational Methods for Measuring the Difference of Empirical Distributions. *American Journal of Agricultural Economics,* 87 (2), 353-365.

Portland Parks and Recreation (2016) *Urban Forest Action Plan: 2015 Implementation Update*. Portland, USA: Portland Parks and Recreation.

Posner, S., Getz, C. and Ricketts, T. (2016) Evaluating the impact of ecosystem service assessments on decision-makers. *Environmental Science & Policy,* 64, 30-37.

Potschin-Young, M., Czúcz, B., Liquete, C., Maes, J., Rusch, G.M. and Haines-Young, R. (2017) Intermediate ecosystem services: An empty concept? *Ecosystem Services,* 27, 124-126.

Potschin, M.B. and Haines-Young, R.H. (2011) Ecosystem services: Exploring a geographical perspective. *Progress in Physical Geography,* 35 (5), 575-594.

Poudyal, N.C., Siry, J.P. and Bowker, J.M. (2010) Urban forests' potential to supply marketable carbon emission offsets: A survey of municipal governments in the United States. *Forest Policy and Economics,* 12 (6), 432-438.

Prokofieva, I. and Gorriz, E. (2013) Institutional analysis of incentives for the provision of forest goods and services: An assessment of incentive schemes in Catalonia (north-east Spain). *Forest Policy and Economics,* 37, 104-114.

Public Health England (2016) *Public Health Outcomes Framework: Trends for Southampton - Fraction of mortality attributable to particulate air pollution*. Available from: https://fingertips.phe.org.uk/profile/public-health-outcomes-framework/data#page/4/gid/1000043/pat/6/par/E12000008/ati/102/are/E06000045 [Accessed 4th June 2018].

Pwc (2010) *Biodiversity and business risk: A Global Risks Network briefing*. Geneva, Switzerland: World Economic Forum. Available from: https://www.pwc.co.uk/assets/pdf/wef-biodiversity-and-business-risk.pdf.

Pwc (2011) *14th Annual Global CEO Survey. Growth reimagined: Prospects in emerging markets drive CEO confidence*. Online: Pricewaterhousecoopers. Available from: https://www.pwc.com/gx/en/ceo-survey/pdf/pwc_14th_annual_global_ceo_survey_e.pdf.

Pwc (2017) *20th CEO Survey: 20 years inside the mind of the CEO... What's next?* Online: Pricewaterhousecoopers. Available from: https://www.pwc.com/gx/en/ceo-agenda/ceosurvey/2017/gx/data-explorer.html.

Qsr International (2012) NVivo*,* 10 ed. Cambridge, MA: QSR International Pty Ltd. Available from: http://www.qsrinternational.com/.

Qsr International (2015) NVivo*,* 11 ed. Cambridge, MA: QSR International Pty Ltd. Available from: http://www.qsrinternational.com/.

Que, S., Awuah-Offei, K., Weidner, N. and Wang, Y. (2017) Discrete choice experiment validation: A resource project case study. *Journal of Choice Modelling,* 22, 39-50.

Rabinowitz, R. and D'este-Hoare, J. (2010) *The Feasibility of Creating a Funding Mechanism for UK Carbon Reduction Projects*. Bre. Available from: http://www.ukcarbonreporting.org/filelibrary/IP17_10.pdf.

Rakotonarivo, O.S., Schaafsma, M. and Hockley, N. (2016) A systematic review of the reliability and validity of discrete choice experiments in valuing non-market environmental goods. *Journal of Environmental Management,* 183 (Part 1), 98-109.

Raum, S., Hand, K.L., Hall, C., Edwards, D.M., O'brien, L. and Doick, K.J. (2019) Achieving impact from ecosystem assessment and valuation of urban greenspace: The case of i-Tree Eco in Great Britain. *Landscape and Urban Planning,* 190, 103590.

Read, D.J., Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, C.C. and Snowdon, P. (2009) *Combating climate change – a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change. The synthesis report.* Edinburgh: The Stationery Office.

Reddy, S.M.W., Mcdonald, R.I., S. Maas, A., Rogers, A., Girvetz, E.H., North, J., Molnar, J., Finley, T., Leathers, G. and L. Dimuro, J. (2015) Finding solutions to water scarcity: Incorporating ecosystem service values into business planning at The Dow Chemical Company's Freeport, TX facility. *Ecosystem Services,* 12, 94-107.

Reed, M.S., Bonn, A., Evans, C.D., Joosten, H., Bain, C., Farmer, J., Emmer, I., Couwenberg, J., Moxey, A., Artz, R.R.E., Tanneberger, F., Von Unger, M., Smyth, M., Birnie, R., Inman, I., Smith, S., Quick, T., Cowap, C. and Prior, S. (2013) *Peatland Code research project. Final Report.* London: Defra.

Richert, C., Erdlenbruch, K. and Figuières, C. (2017) The determinants of households' flood mitigation decisions in France - on the possibility of feedback effects from past investments. *Ecological Economics,* 131, 342-352.

Rimell, W. (2018) Clean Air Zone could cost commercial vehicles up to £100 a day to enter Southampton. *Daily Echo*, 18th June 2018. Available from: https://www.dailyecho.co.uk/news/16296782.clean-air-zone-could-cost-commercial-vehicles-up-to-100-a-day-to-enter-southampton/.

Rinne, J. and Primmer, E. (2016) A Case Study of Ecosystem Services in Urban Planning in Finland: Benefits, Rights and Responsibilities. *Journal of Environmental Policy & Planning,* 18 (3), 286-305.

Roberts, D.C., Boyer, T.A. and Lusk, J.L. (2008) Preferences for environmental quality under uncertainty. *Ecological Economics,* 66 (4), 584-593.

Rode, J., Le Menestrel, M. and Cornelissen, G. (2017) Ecosystem Service Arguments Enhance Public Support for Environmental Protection - But Beware of the Numbers! *Ecological Economics,* 141, 213-221.

Roe, M. and Mell, I. (2013) Negotiating value and priorities: evaluating the demands of green infrastructure development. *Journal of Environmental Planning and Management,* 56 (5), 650-673.

Roesch-Mcnally, G.E. and Rabotyagov, S.S. (2016) Paying for Forest Ecosystem Services: Voluntary Versus Mandatory Payments. *Environmental Management,* 57 (3), 585-600.

Rogers, K., Sacre, K., Goodenough, J. and Doick, K. (2015) *Valuing London's Urban Forest: Results of the London i-Tree Eco Project (Summary)*. London, T.

Rolfe, J. and Windle, J. (2010) Valuing protection of the Great Barrier Reef with choice modelling by management policy options. Paper presented at 54th Annual Australian Agricultural and Resource Economics Society Conference, Adelaide, Australia, 10-12th February 2010.

Rolfe, J. and Windle, J. (2015) Do Respondents Adjust Their Expected Utility in the Presence of an Outcome Certainty Attribute in a Choice Experiment? *Environmental and Resource Economics,* 60 (1), 125-142.

Rolls, S. and Sunderland, T. (2014) *Microeconomic Evidence for the Benefits of Investment in the Environment 2 (MEBIE2)*. Natural England.

Rondinelli, D.A. and Berry, M.A. (2000) Environmental citizenship in multinational corporations: social responsibility and sustainable development. *European Management Journal,* 18 (1), 70-84.

Rose, J.M. and Bliemer, M.C.J. (2009) Constructing Efficient Stated Choice Experimental Designs. *Transport Reviews,* 29 (5), 587-617.

Rothstein, H. and Downer, J. (2012) 'Renewing Defra': Exploring the Emergence of Risk-Based Policymaking in Uk Central Government. *Public Administration,* 90 (3), 781-799.

Rowcroft, P., Smith, S., Clarke, L., Thomson, K. and Reed, M. (2011) *Barriers and opportunities for use of payment for ecosystems services*. London, UK: URS Scott Wilson.

Rowland, C.S., Morton, R.D., Carrasco, L., Mcshane, G., O'neil, A.W. and Wood, C.M. (2017) *Land Cover Map 2015 (25m raster, GB)*. NERC Environmental Information Data Centre. Available from: https://doi.org/10.5285/bb15e200-9349-403c-bda9-b430093807c7.

Roy, S., Byrne, J. and Pickering, C. (2012) A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. *Urban Forestry & Urban Greening,* 11 (4), 351-363.

Rupp, T. (2008) *Meta Analysis of Crime and Deterrence: A Comprehensive Review of the Literature*. Norderstedt, Germany: Books on Demand GmbH.

Salbitano, F., Borelli, S., Conigliaro, M. and Chen, Y. (2016) *Guidelines on urban and peri-urban forestry*. Rome, Italy: Food and Agriculture Organisation of the United Nations (Fao).

Salles, J.-M. (2011) Valuing biodiversity and ecosystem services: Why put economic values on Nature? *Comptes Rendus Biologies,* 334 (5), 469-482.

Salmond, J.A., Tadaki, M., Vardoulakis, S., Arbuthnott, K., Coutts, A., Demuzere, M., Dirks, K.N., Heaviside, C., Lim, S., Macintyre, H., Mcinnes, R.N. and Wheeler, B.W. (2016) Health and climate related ecosystem services provided by street trees in the urban environment. *Environ Health,* 15 Suppl 1, 36.

Samuelson, P. (1947) *Foundations of economic analysis (1983 edition)*. Cambridge, MA, USA: Harvard University Press.

Sander, H.A. and Zhao, C. (2015) Urban green and blue: Who values what and where? *Land Use Policy,* 42, 194-209.

Sattler, C. and Matzdorf, B. (2013) PES in a nutshell: From definitions and origins to PES in practice—Approaches, design process and innovative aspects. *Ecosystem Services,* 6 (Supplement C), 2-11.

Sattler, C., Trampnau, S., Schomers, S., Meyer, C. and Matzdorf, B. (2013) Multi-classification of payments for ecosystem services: How do classification characteristics relate to overall PES success? *Ecosystem Services,* 6, 31-45.

Scarpa, R. and Thiene, M. (2005) Destination Choice Models for Rock Climbing in the Northeastern Alps: A Latent-Class Approach Based on Intensity of Preferences. *Land Economics,* 81 (3), 426-444.

Schomers, S. and Matzdorf, B. (2013) Payments for ecosystem services: A review and comparison of developing and industrialized countries. *Ecosystem Services,* 6, 16-30.

Schomers, S., Sattler, C. and Matzdorf, B. (2015) An analytical framework for assessing the potential of intermediaries to improve the performance of payments for ecosystem services. *Land Use Policy,* 42, 58-70.

Schroeder, H., Flannigan, J. and Coles, R. (2006) Residents' Attitudes Toward Street Trees in the UK and US Communities. *Arboriculture & Urban Forestry,* 32 (5), 236-246.

Schubert, P., Ekelund, N.G.A., Beery, T.H., Wamsler, C., Jonsson, K.I., Roth, A., Stalhammar, S., Bramryd, T., Johansson, M. and Palo, T. (2018) Implementation of the ecosystem services approach in Swedish municipal planning. *Journal of Environmental Policy & Planning,* 20 (3), 298-312.

Scott, A. (2019) to Davies, H.,

Scott, A., Hölzinger, O. and Sadler, J. (2017) *Making Plans for Green Infrastructure in England: Review of National Planning and Environmental Policies and Project Partners' Plans*. Online: Northumbria University & University of Birmingham.

Scottish Executive (2006) *The Scottish Forestry Strategy*. Edinburgh: Forestry Commission Scotland.

Scottish Government (2014) *Scottish Government Urban Rural Classification.* Available from: http://www.gov.scot/Topics/Statistics/About/Methodology/UrbanRuralClassification. [Accessed 6th April 2016].

Scottish Government (2019) *Scotland's Forestry Strategy 2019–2029*. Edinburgh, UK: Scottish Government.

Sheremet, O., Ruokamo, E., Juutinen, A., Svento, R. and Hanley, N. (2018) Incentivising Participation and Spatial Coordination in Payment for Ecosystem Service Schemes: Forest Disease Control Programs in Finland. *Ecological Economics,* 152, 260-272.

Shih, T.-H. and Fan, X. (2009) Comparing response rates in e-mail and paper surveys: A meta-analysis. *Educational Research Review,* 4 (1), 26-40.

Shrestha, R.K. and Alavalapati, J.R.R. (2004) Valuing environmental benefits of silvopasture practice: a case study of the Lake Okeechobee watershed in Florida. *Ecological Economics,* 49 (3), 349-359.

Simonsohn, U. (2009) Direct risk aversion: evidence from risky prospects valued below their worst outcome. *Psychol Sci,* 20 (6), 686-692.

Smith, S., Rowcroft, P., Everard, M., Couldrick, L., Reed, M., Rogers, H., Quick, T., Eves, C. and White, C. (2015) *Payments for Ecosystem Services: A Best Practice Guide*. London: Defra.

Snyder, C. and Nicholson, W. (2012) *Microeconomic Theory: Basic Principles and Extensions*, 11 ed. Canada: Southwestern Cengage Learning.

Soares, A.L., Rego, F.C., Mcpherson, E.G., Simpson, J.R., Peper, P.J. and Xiao, Q. (2011) Benefits and costs of street trees in Lisbon, Portugal. *Urban Forestry & Urban Greening,* 10 (2), 69-78.

Sommerville, M., Jones, J.P.G., Rahajaharison, M. and Milner-Gulland, E.J. (2010) The role of fairness and benefit distribution in community-based Payment for Environmental Services interventions: A case study from Menabe, Madagascar. *Ecological Economics,* 69 (6), 1262-1271.

Song, X.P., Tan, P.Y., Edwards, P. and Richards, D. (2018) The economic benefits and costs of trees in urban forest stewardship: A systematic review. *Urban Forestry & Urban Greening,* 29, 162-170.

Soto, J.R., Escobedo, F.J., Khachatryan, H. and Adams, D.C. (2018) Consumer demand for urban forest ecosystem services and disservices: Examining trade-offs using choice experiments and best-worst scaling. *Ecosystem Services,* 29, 31-39.

Southampton City Council (2014) *Southampton Local Flood Risk Management Strategy. Strategic Environmental Assessment: Environmental Report*. Southampton: Southampton City Council.

Southampton City Council (2018) *Clean air zone consultation*. Available from: http://www.southampton.gov.uk/council-democracy/have-your-say/clean-air-consultation.aspx [Accessed 5th May 2019].

Spangenberg, J.H. and Settele, J. (2010) Precisely incorrect? Monetising the value of ecosystem services. *Ecological Complexity,* 7 (3), 327-337.

Spangenberg, J.H., Von Haaren, C. and Settele, J. (2014) The ecosystem service cascade: Further developing the metaphor. Integrating societal processes to accommodate social processes and planning, and the case of bioenergy. *Ecological Economics,* 104, 22-32.

Spragg, J., Davies, H. and Evans, S. (2017) *Low Carbon Electricity (Research Briefing)*. Cardiff, UK: National Assembly for Wales Research Service.

Stadtler, L. and Lin, H. (2017) Moving to the Next Strategy Stage: Examining Firms' Awareness, Motivation and Capability Drivers in Environmental Alliances. *Business Strategy and the Environment,* 26 (6), 709-730.

Steenberg, J.W.N. (2018) People or place? An exploration of social and ecological drivers of urban forest species composition. *Urban Ecosystems,* 21 (5), 887-901.

Steenberg, J.W.N., Duinker, P.N. and Nitoslawski, S.A. (2019) Ecosystem-based management revisited: Updating the concepts for urban forests. *Landscape and Urban Planning,* 186, 24-35.

Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A. and Kalof, L. (1999) A Value-Belief-Norm Theory of Support for Social Movements: The Case of Environmentalism. *Research in Human Ecology,* 6 (2), 81-97.

Suich, H., Howe, C. and Mace, G. (2015) Ecosystem services and poverty alleviation: A review of the empirical links. *Ecosystem Services,* 12, 137-147.

Sunderland, T., Rolls, S. and Butterworth, T. (2015) Chapter 4: Putting economic values on green infrastructure improvements IN: Sinnett, S., Smith, N. and Burgess, S. (eds.) *Handbook on Green Infrastructure: Planning, Design and Implementation*. Cheltenham: Edward Elgar Publishing Limited.

Sunstein, C.R., Bobadilla-Suarez, S., Lazzaro, S.C. and Sharot, T. (2017) How People Update Beliefs about Climate Change- Good News and Bad News. *Cornell Law Review,* 102, 1431-1444.

Swade, K., Walker, A. and Walton, M. (2013) *Community Management of Local Authority Woodlands in England. A Report for Forest Research.* London: Shared Assets.

Swait, J. and Louviere, J. (1993) The Role of the Scale Parameter in the Estimation and Comparison of Multinomial Logit Models. *Journal of Marketing Research,* 30 (3), 305-314.

Swedish Environmental Protection Agency (2006) *An instrument for assessing the quality of environmental valuation studies*. Stockholm, Sweden: Naturvårdsverket.

Taber, C.S. and Lodge, M. (2006) Motivated skepticism in the evaluation of political beliefs. *American Journal of Political Science,* 50 (3), 755-769.

Tacconi, L. (2012) Redefining payments for environmental services. *Ecological Economics,* 73, 29-36.

Teeb (2009) *The Economics of Ecosystems and Biodiversity for National and International Policy Makers*. Unep.

Teeb (2010) *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. London: Earthscan.

Teeb (2011) *TEEB manual for cities: Ecosystem services in urban management*. www.teebweb.org.

Teeb (2012) *The Economics of Ecosystems and Biodiversity in Business and Enterprise*. London and New York: Earthscan.

The Nature Conservancy (2016) *Planting Healthy Air: A global analysis of the role of urban trees in addressing particulate matter pollution and extreme heat*. Arlington, Virginia, USA: The Nature Conservancy.

The Open University (no date) *Treezilla: the monster map of trees*. Available from: https://www.treezilla.org/treezilla/map/.

The R Foundation (2018) R*,* 3.5.1 ed. https://www.r-project.org/: CRAN. Available from: https://cran.r-project.org/bin/windows/base/old/3.5.1/.

The World Bank (2017) *Urban population (% of total)*. Available from: https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS [Accessed 27th September 2017].

The World Bank (2018) *Urban population (% of total)*. Available from: http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?page=6 [Accessed 20th February 2019].

Thompson, B.S. (2018) Payments for ecosystem services and corporate social responsibility: Perspectives on sustainable production, stakeholder relations, and philanthropy in Thailand. *Business Strategy and the Environment*.

Thompson, K., Sherren, K. and Duinker, P.N. (2019) The use of ecosystem services concepts in Canadian municipal plans. *Ecosystem Services,* 38, 100950.

Thomson, S.D. (1989) *Southampton Common*, 2nd ed. Southampton, UK: City of Southampton Society.

Tinch, R. (2009) *Assessing Socio-economic Benefits of Natura 2000 – a Case Study on the ecosystem service provided by the SUSTAINABLE CATCHMENT MANAGEMENT PROGRAMME. Output of the project Financing Natura 2000: Cost estimate and benefits of Natura 2000 (Contract*

No.: 070307/2007/484403/MAR/B2). . London: Eftec. Available from: http://ec.europa.eu/environment/nature/natura2000/financing/docs/scamp_case_study.pdf.

Tinch, R., Beaumon, N., Sunderlan, T., Ozdemiroglu, E., Barton, D., Bowe, C., Borger, T., Burgess, P., Cooper, C.N., Faccioli, M., Failler, P., Gkolemi, I., Kumar, R., Longo, A., Mcvittie, A., Morris, J., Park, J., Ravenscroft, N., Schaafsma, M., Vause, J. and Ziv, G. (2019) Economic valuation of ecosystem goods and services: a review for decision makers. *Journal of Environmental Economics and Policy,* 8 (4), 359-378.

Toerien, M. and Wilkinson, S. (2004) Exploring the depilation norm: a qualitative questionnaire study of women's body hair removal. *Qualitative Research in Psychology,* 1 (1), 69-92.

Toronto City Council (2013) *Sustaining and Expanding the Urban Forest: Toronto's Strategic Forest Management Plan 2012-2022*. Toronto, Canada: Toronto City Council.

Torres, C., Faccioli, M. and Riera Font, A. (2017) Waiting or acting now? The effect on willingness-to-pay of delivering inherent uncertainty information in choice experiments. *Ecological Economics,* 131, 231-240.

Train, K.E. (2009) *Discrete Choice Methods with Simulation*, 2 ed. Cambridge: Cambridge University Press.

Train, K.E., Mcfadden, D.L. and Goett, A.A. (1987) Consumer Attitudes and Voluntary Rate Schedules for Public Utilities. *The Review of Economics and Statistics,* 69 (3), 383-391.

Tran, Y.L., Siry, J.P., Bowker, J.M. and Poudyal, N.C. (2017) Atlanta Households' Willingness to Increase Urban Forests to Mitigate Climate Change. *Urban Forestry & Urban Greening*.

Tree Canada (2012) *Canadian Urban Forest Strategy 2013-2018*. Ottawa, Canada: Tree Canada.

Treetime Edinburgh (2015) *Sponsorship*. Available from: http://www.tree-time.com/category/sponsorship/ [Accessed 13th October 2017].

Tu, G., Abildtrup, J. and Garcia, S. (2016) Preferences for urban green spaces and peri-urban forests: An analysis of stated residential choices. *Landscape and Urban Planning,* 148, 120-131.

Turner, R.K. and Daily, G.C. (2008) The Ecosystem Services Framework and Natural Capital Conservation. *Environmental and Resource Economics,* 39 (1), 25-35.

Tyrväinen, L. (2001) Economic valuation of urban forest benefits in Finland. *Journal of Environmental Management,* 62 (1), 75-92.

Uk Nea (2014) *The UK National Ecosystem Assessment Follow-on: Synthesis of the key findings*. Cambridge: Unep-Wcmc.

Ulmer, J.M., Wolf, K.L., Backman, D.R., Tretheway, R.L., Blain, C.J.A., O'neil-Dunne, J.P.M. and Frank, L.D. (2016) Multiple health benefits of urban tree canopy: The mounting evidence for a green prescription. *Health & Place,* 42, 54-62.

Unfpa (2007) *State of World Population 2007: Unleashing the Potential of Urban Growth*. New York, USA: United Nations Population Fund.

United Nations (2015) *Population Division: 2014 Revision of World Urbanization Prospects* Available from: https://esa.un.org/unpd/wup/ [Accessed 27th September 2017].

Upton, V., Dhubháin, Á.N. and Bullock, C. (2012) Preferences and values for afforestation: The effects of location and respondent understanding on forest attributes in a labelled choice experiment. *Forest Policy and Economics,* 23, 17-27.

Urban Fwac Network (2015) *Our vision for a resilient urban forest*. Urban Fwac Network.

Urban Task Force (1999) *Towards an Urban Renaissance*. Wetherby, UK: Department of the Environment, Transport and the Regions.

Us Global Change Research Program (2018) *Fourth National Climate Assessment: Volume II - Impacts, Risks, and Adaptation in the United States*. Washington, DC, USA: Us Global Change Research Program.

Usda Forest Service (no date-a) *i-Tree Canopy*. Available from: https://canopy.itreetools.org/ [Accessed 10th February 2017].

Usda Forest Service (no date-b) *i-Tree Eco*. Available from: https://www.itreetools.org/eco/overview.php [Accessed 30th August 2016].

Valatin, G., Abildtrup J, Accastello C, Al-Tawaha A, Andreucci M, Atanasova S, Avdibegović M, Baksic N, Banasik K, Barquin J, Barstad J, Bastakova V, Becirovic D, Begueria S, Bethers U, Bihunova

M, Blagojevic B, Bösch M, Bournaris T, Cao Y, Carvalho-Santos C, Chikalanov A, Cunha E Sá M, Czyżyk K, Daly H, Davies H, Del Campo A, Groot R, De Vreese R, Dostál T, El Mokaddem A, Finér L, Evans R, Fiquepron J, Frac M, Futter M, Garcia S, Gatto P, Geneletti D, Gezik V, Giupponi C, González-Sanchís M, Gordillo F, Gorriz E, Grigorova Y, Heinsoo K, Hochbichler E, Högbom L, Image M, Jacobsen J, Japelj A, Jelic S, Junk J, Juhasz C, Kagalou I, Kelly-Quinne M, Klamerus-Iwan A, Kluvankova T, Koeck R, Konovska I, Krajter Ostoic S, Krc J, Lavnyy V, Leonardi A, Libiete Z, Little D, Lo Porto A, Loukas A, Lyubenova M, Maric B, Martínez-López J, Martinez I, Maxim A, Metslaid M, Melvin A, Costică M, Mincev I, Morkvenas Z, Nevenic R, Nisbet T, O'huallachain D, Olschewski R, Östberg J, Oszust K, Ovando P, Paletto A, Parpan T, Pettenella D, Malovrh Š, Planinšek Š, Podlipná R, Posavec S, Potočki K, Prokofieva I, Quinteiro P, Radocz L, Ristic R, Robert N, Rugani B, Sabanovic J, Sarvasova Z, Savoska S, Schleppi P, Schueler G, Shannon M, Silgram M, Srdjevic B, Stefan G, Stijovic A, Strange N, Tattari S, Teofilovski A, Termansen M, Thorsen B, Toth A, Trebs I, Tmušić N, Vasiliades L, Vedel S, Ventrubová K, Vuletic D, Winkel G, Yao R, Young S, Yousefpour R, Zahvoyska L, Zhang D, Zhou J and E, Ž. (2017) PESFOR-W: Improving the design and environmental effectiveness of woodlands for water Payments for Ecosystem Services. *Research Ideas and Outcomes,* 3 (e13828), 1-28.

Van De Sand, I. (2012) Payments for Ecosystem Services in the Context of Adaptation to Climate Change. *Ecology and Society,* 17 (1).

Van Den Burg, S.W.K. and Bogaardt, M.J. (2014) Business and biodiversity: A frame analysis. *Ecosystem Services,* 8, 178-184.

Van Der Jagt, A.P.N. and Lawrence, A. (2015) *Trees and Woods in Scottish Towns: The role of Local Authorities*. Roslin, Midlothian: Forest Research.

Van Der Jagt, A.P.N. and Lawrence, A. (2019) Local government and urban forest governance: insights from Scotland. *Scandinavian Journal of Forest Research,* 34 (1), 53-66.

Van Hecken, G., Bastiaensen, J. and Windey, C. (2015) Towards a power-sensitive and socially-informed analysis of payments for ecosystem services (PES): Addressing the gaps in the current debate. *Ecological Economics,* 120, 117-125.

Van Zoest, J. and Hopman, M. (2014) Taking the economic benefits of green space into account: The story of the Dutch TEEB for Cities project. *Urban Climate,* 7, 107–114.

Vandermeulen, V., Verspecht, A., Vermeire, B., Van Huylenbroeck, G. and Gellynck, X. (2011) The use of economic valuation to create public support for green infrastructure investments in urban areas. *Landscape and Urban Planning,* 103 (2), 198-206.

Vatn, A. (2010) An institutional analysis of payments for environmental services. *Ecological Economics,* 69 (6), 1245-1252.

Vatn, A. (2015) Markets in environmental governance — From theory to practice. *Ecological Economics,* 105, 97-105.

Vatn, A., Barton, D.N., Lindhjem, H., Movik, S., Ring, I. and Santos, R. (2011) *Can markets Protect Biodiversity? An Evaluation of Different Financial Mechanisms.* Aas, Norway: Norwegian University of Life Sciences.

Vecchiato, D. and Tempesta, T. (2013) Valuing the benefits of an afforestation project in a peri-urban area with choice experiments. *Forest Policy and Economics,* 26, 111-120.

Veronesi, M., Chawla, F., Maurer, M. and Lienert, J. (2014) Climate change and the willingness to pay to reduce ecological and health risks from wastewater flooding in urban centers and the environment. *Ecological Economics,* 98 (Supplement C), 1-10.

Vesely, É.-T. (2007) Green for green: The perceived value of a quantitative change in the urban tree estate of New Zealand. *Ecological Economics,* 63 (2–3), 605-615.

Viscusi, W.K. (1985) A Bayesian perspective on biases in risk perception. *Economics Letters,* 17 (1), 59-62.

Vivid Economics (2016) *The contribution made by Sheffield's parks to the wellbeing of the city's citizens*. London, UK: Vivid Economics.

Voltaire, L., Donfouet, H.P.P., Pirrone, C. and Larzillière, A. (2017) Respondent Uncertainty and Ordering Effect on Willingness to Pay for Salt Marsh Conservation in the Brest Roadstead (France). *Ecological Economics,* 137, 47-55.

Von Neumann, J. and Morgenstern, O. (1947) *Theory of Games and Economic Behavior.* . Princeton, NJ, USA: Princeton University Press.

Walsall Council (2016) *Urban Forestry Strategy for Walsall Council 2016- 2026*. Walsall, UK: Walsall Council.

Wamsler, C. (2015) Mainstreaming ecosystem-based adaptation: transformation toward sustainability in urban governance and planning. *Ecology and Society,* 20 (2).

Wassmer, U., Paquin, R. and Sharma, S. (2014) The Engagement of Firms in Environmental Collaborations: Existing Contributions and Future Directions. *Business & Society,* 53 (6), 754-786.

Waylen, K.A. and Martin-Ortega, J. (2018) Surveying views on Payments for Ecosystem Services: Implications for environmental management and research. *Ecosystem Services,* 29, 23-30.

Weber, M. (2008) The business case for corporate social responsibility: A company-level measurement approach for CSR. *European Management Journal,* 26 (4), 247-261.

Weber, S. (2016) *3 Cities Taking Urban Forestry to the Next Level*. Available from: https://www.wri.org/blog/2016/03/3-cities-taking-urban-forestry-next-level [Accessed 29th January 2019].

Welsh Assembly Government (2009) *Woodlands for Wales: The Welsh Assembly Government's Strategy for Woodlands and Trees*. Forestry Commission Wales.

Welsh Government (2018) *Woodlands for Wales: The Welsh Government's Strategy for Woodlands and Trees* Cardiff, UK: Welsh Government,.

Wertz-Kanounnikoff, S., Locatelli, B., Wunder, S. and Brockhaus, M. (2011) Ecosystem-based adaptation to climate change: What scope for payments for environmental services? *Climate and Development,* 3 (2), 143-158.

Wibbenmeyer, M.J., Hand, M.S., Calkin, D.E., Venn, T.J. and Thompson, M.P. (2013) Risk preferences in strategic wildfire decision making: a choice experiment with U.S. wildfire managers. *Risk Analysis,* 33 (6), 1021-1037.

Wielgus, J., Gerber, L.R., Sala, E. and Bennett, J. (2009) Including risk in stated-preference economic valuations: Experiments on choices for marine recreation. *Journal of Environmental Management,* 90 (11), 3401-3409.

Wilkes-Allemann, J., Pütz, M., Hirschi, C. and Fischer, C. (2015) Conflict situations and response strategies in urban forests in Switzerland. *Scandinavian Journal of Forest Research,* 30 (3), 204-216.

Wolf, K.L. (2004a) Nature in the retail environment: Comparing consumer and business response to urban forest conditions. *Landscape Journal,* 23 (1), 40-51.

Wolf, K.L. (2004b) Trees and business district preferences: A case study of Athens, Georgia, U.S. *Journal of Arboriculture,* 30 (6), 336-346.

Wolf, K.L. (2009) More in Store: Research on City Trees and Retail. *Arborist News,* 18 (2), 22-27.

Woodruff, S.C. and Bendor, T.K. (2016) Ecosystem services in urban planning: Comparative paradigms and guidelines for high quality plans. *Landscape and Urban Planning,* 152, 90-100.

World Health Organization (2016) *Global Urban Ambient Air Pollution Database (update 2016)*. Available from: http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/ [Accessed 28/02/2018].

Wow Nature (2018) *PadovaO2*. Available from: http://www.wownature.eu/host/padova-o2/.

Wrexham County Borough Council (2015) *Wrexham's Tree and Woodland Draft Strategy (2015 – 2025)*. Wrexham County Borough Council. Available from: http://www.wrexham.gov.uk/assets/pdfs/env_services/trees/draft_tree_strategy2015.pdf.

Wright, W.C.C., Eppink, F.V. and Greenhalgh, S. (2017) Are ecosystem service studies presenting the right information for decision making? *Ecosystem Services,* 25, 128-139.

Wunder, S. (2005) *Payments for environmental services- some nuts and bolts*. Jakarta, Indonesia: Center for International Forestry Research.

Wunder, S. (2008) Necessary Conditions for Ecosystem Service Payments. Paper presented at Economics and Conservation in the Tropics: A Strategic Dialogue.

Wunder, S., Engel, S. and Pagiola, S. (2008) Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries. *Ecological Economics,* 65 (4), 834-852.

Young, R.F. (2013) Mainstreaming urban ecosystem services: A national survey of municipal foresters. *Urban Ecosystems,* 16 (4), 703-722.

Zaalberg, R., Midden, C., Meijnders, A. and Mccalley, T. (2009) Prevention, Adaptation, and Threat Denial: Flooding Experiences in the Netherlands. *Risk Analysis,* 29 (12), 1759-1778.

Zhang, D.-L., Shou, Y.-X. and Dickerson, R.R. (2009) Upstream urbanization exacerbates urban heat island effects. *Geophysical Research Letters,* 36 (24), n/a-n/a.

Ziter, C.D., Pedersen, E.J., Kucharik, C.J. and Turner, M.G. (2019) Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences,* 116 (15), 7575-7580.