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Research Paper

Achieving impact from ecosystem assessment and valuation of urban greenspace: The case of i-Tree Eco in Great Britain

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ABSTRACT

Numerous tools have been developed to assist environmental decision-making, but there has been little examination of whether these tools achieve this aim, particularly for urban environments. This study aimed to evaluate the use of the i-Tree Eco tool in Great Britain, an assessment tool developed to support urban forest management. The study employed a documentary review, an online survey, and interviews in six case study areas to examine five impacts (instrumental, conceptual, capacity-building, enduring connectivity, and culture/attitudes towards knowledge exchange) and to identify which factors inhibited or supported achievement of impact. It revealed that the i-Tree Eco projects had helped to increase knowledge of urban forests and awareness of the benefits they provide. While there was often broad use of i-Tree Eco findings in various internal reports, external forums, and discussions of wider policies and plans, direct changes relating to improved urban forest management, increased funding or new tree policies were less frequent. The barriers we identified which limited impact included a lack of project champions, policy drivers and resources, problems with knowledge transfer and exchange, organisational and staff change, and negative views of trees. Overall, i-Tree Eco, similar to other environmental decision-making tools, can help to improve the management of urban trees when planned as one step in a longer process of engagement with stakeholders and development of new management plans and policies. In this first published impact evaluation of multiple i-Tree Eco projects, we identified eight lessons to enhance the impact of future i-Tree Eco projects, transferable to other environmental decision-making tools.

1. Introduction

1.1. Ecosystem assessment and valuation tools

Since the publication of the Millennium Ecosystem Assessment (MEA, 2005), assessments of ecosystems and the benefits, or ecosystem services, they provide to society and human well-being have been undertaken in many parts of the world at national, regional or local levels (Nikodinoska, Paletto, Pastorella, Granvik, & Franzese, 2018). These involve assessing the state of ecosystems (INBO, 2014; UNEP, 2011), the flow of services from them (Bagstad et al., 2014; Schröter et al., 2018), and placing a value on the benefits those services provide to humans (Costanza et al., 1997; Liv & Opdam, 2014). At the European level, the EU Biodiversity Strategy requires member states to "map and assess the state of ecosystems and their services in their national territory" and to integrate ecosystem services "values into accounting and reporting systems at European Union and national level by 2020" (European Commission, 2011: 15). National Ecosystem Assessments (NEAs) are one way to comply with these requirements and natural capital accounts, comprising regularly updated information about ecosystem services, are considered an important step to operationalise the results of NEAs (Schröter et al., 2016).

While tools to assess ecosystems and the services they provide have proliferated, including computer-based decision support systems (McLaughlin & Jordan, 1999; Reynolds et al., 2007; Stewart, Edwards, & Lawrence, 2013), there has been increasing recognition of a lack of focus on how these could impact on policy, plans and management (Schröter et al., 2016; Stewart et al., 2013). Although the generic factors influencing uptake of decision support tools are well understood (Díez & McIntosh, 2009), mechanisms have been weak to stimulate translation of the results into action (Schröter et al., 2016).

Similarly, there have been few published evaluations exploring

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whether specific tools have informed and influenced environmental decision-making (Díez & McIntosh, 2009; Laurans, Rankovic, Billé, Pirard, & Mermet, 2013; Stewart et al., 2013). Those evaluated have been found to increase awareness of the environment and its value (MacDonald, Bark, & Coggan, 2014), improve knowledge and collaboration around nature's services (Posner, Getz, & Ricketts, 2016), and create conceptual changes in the way people think of a problem (Brunet et al., 2018), which could help lead to future change in management, policy and plans (Beaumont, Mongruel, & Hooper, 2018; MacDonald et al., 2014). Yet, in reviews of impact across projects very few have been found to cause changes in policies and practices (Beaumont et al., 2018; Waite, Kushner, Jungwiwattanaporn, Gray, & Burke, 2015), or rarer still actual change to the environment (Ruckelshaus et al., 2015). This raises the question as to whether ecosystem assessment and valuation tools achieve their stated goal of improving environmental policy and practice.

1.2. Urban trees and forests

With 55% of the world's human population residing in cities (UN, 2017), urban environments are crucially important for sustaining human well-being (Endreny et al., 2017; Nikodinoska et al., 2018). The recognition of the importance of the natural components of urban environments for the wide range of public benefits they provide, however, has lagged behind rural environments. For example, they were not included in the MEA (Haase, Frantzeskaki, & Elmqvist, 2014). Urban trees are a key feature of urban environments, providing an array of public benefits, including cooling, thereby ameliorating the urban heat island effect, reducing pollution, sequestering and storing carbon, mitigating flooding, and providing recreational opportunities and inspiration for culture, art, and design (Davies, Doick, Handley, O'Brien, & Wilson, 2017a; O'Brien et al., 2017). Until recently, the importance of these benefits has not been fully recognised (Davies et al., 2017a; Willis & Petrokofsky, 2017).

In Great Britain (GB), the concept of 'urban forests' first appeared on the policy agenda in the late 1990s (Konijnendijk, 2003). Recognition of the multiple benefits of urban trees slowly grew in GB policy, culminating in a vision for resilient urban forests (UFWACN, 2016a), the Wales Woodland Strategy (Welsh Government, 2018), Scotland's Forestry Strategy (Scottish Government, 2019), and the UK Government's 25-year environment plan which restates their support to major urban tree planting efforts (HM Government, 2018). Policies governing urban tree management, however, are scarce and often provide greater capacity for tree removal than planting or protection (Dandy, 2010). The delegation of decision-making on urban forests to the local government, who can be responsible for up to 75% of the trees in an urban area (UFWACN, 2016b), has also created challenges (Dandy, 2010). The approach of local governments to urban forest management has been described as "risk-averse", "fire-fighting" and lacking strategic, long-term planning, where potential for tree damage to buildings and risk to public safety drive local authorities to manage urban trees to minimise those risks rather than for their public benefits (Britt & Johnston, 2008; Davies, Doick, Hudson, & Schreckenberg, 2017b).

To fully understand how best to manage the urban forest and maximise potential of the numerous benefits it provides, there is a need for greater appreciation by policy-makers, managers, and the public of the urban forest resource and to communicate more effectively the benefits this resource provides (Moffat, 2016). Assessment and valuation tools applied to urban environments, here trees, are seen as opportunities to both raise the profile of urban forests and improve understanding of their management needs (Nowak et al., 2008; Willis & Petrokofsky, 2017). i-Tree Eco is a particularly useful tool as it not only provides evidence of the urban forest resource but also offers a monetary value of some of the benefits trees provide (Nowak et al., 2008). This understanding is important as the financial and human costs of not managing urban forests based on evidence can be substantial (Willis & Petrokofsky, 2017).

1.3. i-Tree tool

i-Tree is a suite of software programmes developed by the United States Department of Agriculture Forest Service and introduced in 2006 (NRS, 2018) to "quantify the benefits and values of trees around the world; aid in tree and forest management and advocacy; [and] show potential risks to tree and forest health" (www.itreetools.org). i-Tree Eco, the most widely used of the software suite, is a package designed to provide data on urban forest structure, composition and state, including canopy cover, species composition and condition (crown dieback) of trees, and the replacement costs of trees (Nowak et al., 2008). The model uses data, collected using standardised field methods (Nowak et al., 2008). The use of field data sets i-Tree Eco apart from many other assessment and valuation tools (Sarajevs, 2011). Using this data, the model also calculates and values the ecosystem services of carbon storage and sequestration, air pollution removal, and avoided water runoff (Nowak et al., 2008). The integration of an assessment of the biophysical state and the economic value of several ecosystem services allows a deeper understanding of the ecological life-support system of urban forests (Nikodinoska et al., 2018).

i-Tree Eco has been applied in 130 countries (NRS, 2018). i-Tree Eco projects involve stages of project design, data collection, data analysis, reporting, and dissemination of findings (www.itreetools.org). i-Tree Eco software is available for anyone to use, though in the UK projects have often been delivered in partnership between various state and private organisations who provide different skills and fulfil different functions within the project (www.itreetools.org). For example, often projects are run with a partnership between a local authority and an external agency with skills in tree assessment, expertise with the i-Tree tools, data analysis, and project reporting. Data collection is often contracted to professional arboriculturalists, though volunteers trained in i-Tree surveying have also been engaged. The United States, where the tool was primarily designed, has adopted i-Tree Eco most prolifically (NRS, 2018). In GB, the first i-Tree Eco project was in Torbay, England, in 2011 and it has now been used in over 20 urban areas (Fig. 1). Although there has been often high-profile use of i-Tree Eco over the past ten years, there has been surprisingly little assessment of impact arising from these projects. Reports of impacts are largely anecdotal, with claims that they improve appreciation of urban trees (Soares et al., 2011), inform management targets (Ordóñez & Duinker, 2013), increase tree budgets (Wells, 2012), and inspire tree planting schemes (Morgenroth & Östberg, 2017).

In GB, there has been a single unpublished internal evaluation of Wrexham's i-Tree Eco survey (Jaluzot & Evison, 2016). The key impacts were identified as "improving understanding of the state of Wrexham's urban forest" and "raising awareness of its value" and the "need for investment in trees". However, it is unclear to what extent the Wrexham or any other British i-Tree Eco survey has led to better urban forest management or protection and expansion of urban forest across local authorities.

This study aimed to explore the impacts of ecosystem assessments and valuations, using the i-Tree Eco tool as an example. However, the findings are more broadly applicable across other ecosystem assessments. As a sector with a strong focus on policy-makers and practitioners, forestry provides a compelling context for this kind of analysis. The study intended to identify realised impacts across five impact areas listed below, barriers to impact and solutions to overcome these barriers. This paper also offers lessons learned from the evaluation of the i-Tree Eco tool and proposes suggestions for its future development and use which are of broad relevance to other assessment and valuation tools and protocols.

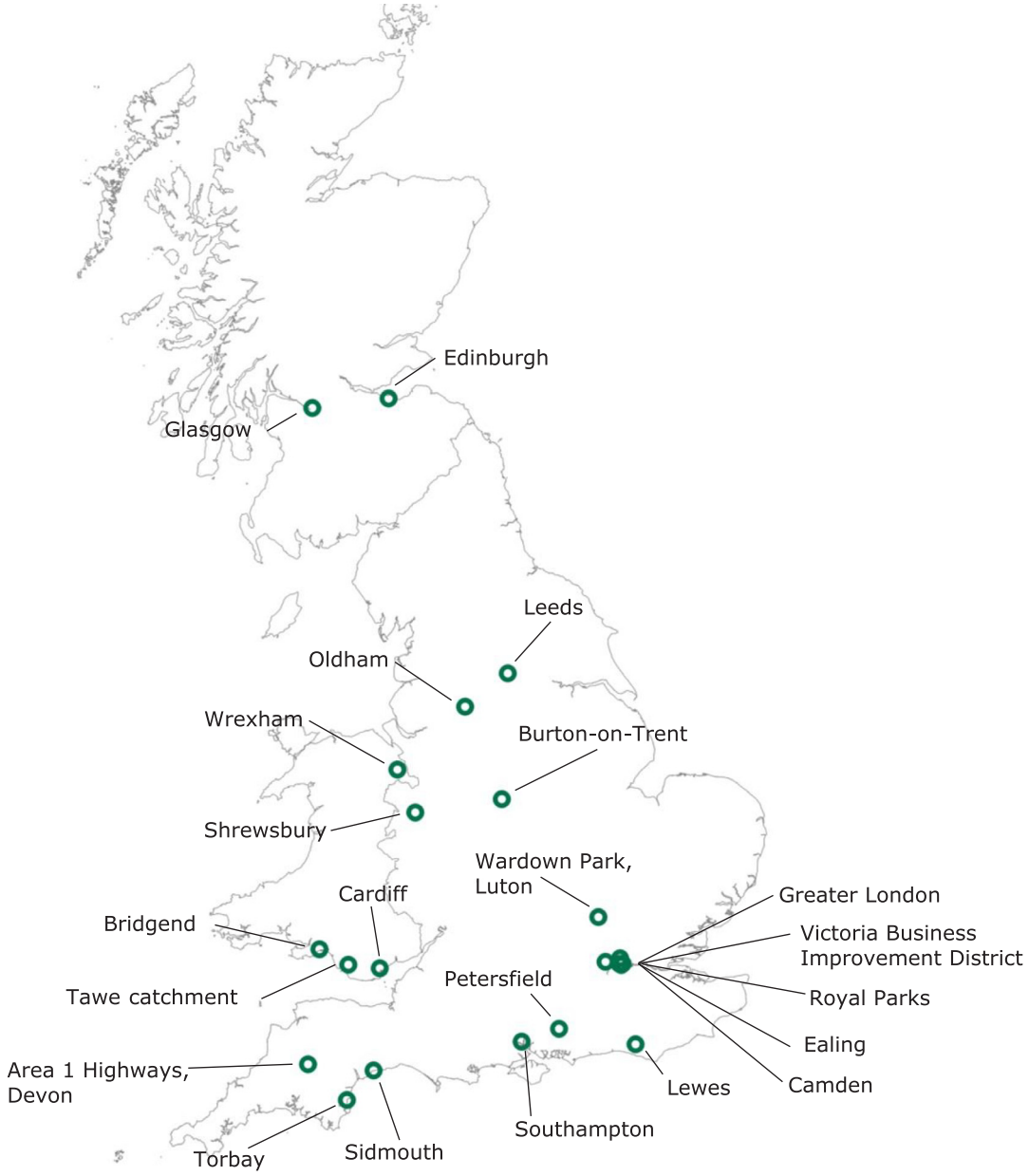


Fig. 1. Location of the 22 i-Tree Eco projects known to be completed or in progress in GB as of January 2018.

2. Conceptual framework

Impact generation can be complex (Morton, 2015a; Stewart et al., 2013). For this reason, we used an established impact evaluation framework that helps to make the processes of impact generation more explicit. The framework, devised by Nutley, Walter, and Davies (2007) and Meagher, Lyall, and Nutley (2008), and further developed and tested by Edwards, Morris, and O'Brien (2017) and Edwards and Meagher (2019), uses a comprehensive set of five types of impacts; it has been used or referred to in a number of other impact evaluation works (Meagher & Lyall, 2013; Meagher, 2012; Reed, 2016). The framework comprises five impact categories: 'instrumental', 'conceptual', 'capacity-building', 'enduring connectivity', and 'culture/attitudes towards knowledge exchange' (Edwards & Meagher, 2019; Edwards et al., 2017). The breadth of impact types considered in this impact evaluation framework allows for a particularly broad and deep reflection of the impacts of i-Tree Eco projects in the UK. A further advantage of this comprehensive impact evaluation framework is that it broadens attention beyond instrumental impacts to include other, less direct or tangible types of impact, which can draw together isolated impacts into an on-going narrative that can support learning and dissemination (Edwards & Meagher, 2019). The framework fills a gap in existing academic literature and evaluation practice by offering a set of 'building blocks' with which researchers and stakeholders can construct impact narratives that understand and explain what changed and how these changes occurred. Moreover, it has already been applied in a forestry context (Edwards & Meagher, 2019; Edwards et al., 2017).

Edwards et al., (2017) and Edwards and Meagher (2019) provide the following definitions for each impact:

Instrumental: changes to plans, decisions, behaviours, practices, actions, policies
Conceptual: changes to knowledge, awareness, attitudes, emotions
Capacity-building: changes to skills and expertise
Enduring connectivity: changes to the number and quality of relationships and trust

Culture/attitudes towards knowledge exchange, and research impact itself e.g. researchers and end-users recognise that it can be beneficial to interact from the earliest stages of a project when policy or management problems are being framed and translated into questions for research and development.

Measuring impacts is not easy, especially when seeking to quantify changes over long time periods that can be attributed to a given intervention (Meagher et al., 2008; Molas-Gallart, Tang, & Morrow, 2000). Most impact processes are complex and include ways in which research is conducted and communicated, and involve many actors interacting over time (Fazey et al., 2014; Meagher & Lyall, 2013). The ways in which research is taken up and used in policy and practice settings means that linking research processes or outputs to wider changes is difficult, and timescales are hard to predict (Morton, 2015a). Most impacts are incremental and, at least in the short term, "more of a step in a process moving toward impact rather than a full-fledged impact" (Meagher et al., 2008: 170). It has therefore been argued that qualitative approaches to impact evaluation, that focus on insights gained through feedback from stakeholders on the processes that have led or could lead towards impact to inform future action, are, at times, more helpful than attempts to quantify or even monetise impacts (Meagher & Lyall, 2013). At other times, a combination of both may be the best choice (Rau, Goggins, & Fahy, 2018; Reed, 2018).

3. Materials and methods

For this study, we applied a mixed methods approach, comprising qualitative and quantitative methods. This allowed us to triangulate the findings (Jupp, 2006) which enhanced their robustness (Meagher et al., 2008). It also provided greater in-depth understanding of the various impacts (Morton, 2015a) of i-Tree Eco projects. We began with a documentary review (Savin-Baden & Howell-Major, 2013), followed by an online survey (Bryman, 2012), and then stakeholder interviews (Silverman, 2001). The conceptual framework was used for the online survey and the interviews to facilitate synthesis across methods.

The evaluation focused primarily, but not exclusively, on six case studies in GB (Table 1). The case studies were chosen to include a sample across GB, were completed projects and thus had the potential to show impact. Broadly, the i-Tree Eco projects had the same overarching objective: to improve urban tree management through increased awareness of their contribution to society (Table 1). The sample i-Tree projects were contracted by local authorities and conducted by contractors, except for one which was conducted by a local community group through volunteers (Table 1). Each had very similar capacity and potential to fulfil their objective given the involvement of the local authority from the outset, except the Sidmouth project. The documentary review and online survey included data beyond the six case studies. For example, those who completed the online questionnaire included respondents involved in other GB i-Tree Eco projects than the six outlined in Table 1.

3.1. Documentary review of impacts

The documentary review (Bryman, 2012) included policy documents, guidance, legislation, reports, and management plans associated with the case study areas, as well as research-based materials and reports from external organisations which cited i-Tree Eco reports, projects and/or data. It involved an online search (using Google) for policies, plans or reports related to the six case study projects and tree management, with the aim to understand changes in policy or management before and after the i-Tree Eco project. Key word searches were conducted for the terms 'i-Tree', 'tree/woodland', 'policy/strategy'-with each location's name and with associated documents identified from snowballing from these. The references of documents identified and reviewed are listed in Appendix 1. The sources of

Table 1
. Case study summary information.

Location Year	Survey area (ha)	Description of location	Stated aim of project (stated in final reports)	Conducted by	Reference
Torbay (England) 2011	6375	A coastal borough in southern England, spanning the towns of Torquay, Paignton and Brixham	● to gain a better understanding of Torbay's urban forest resource ● to improve the management of the urban forest ● to evaluate its current structure and distribution to obtain a baseline from which to set goals and to monitor changes	Contractors	Rogers et al., 2011
Edinburgh (Scotland) 2012	11,468	The second most populous city in Scotland, a coastal city, and its capital	● to quantify a range of environmental and financial benefits delivered to the community by Edinburgh's urban trees	Contractors	Hutchings et al., 2012
Sidmouth (England) 2014	4654	i-Tree Eco was conducted in the Sid Valley which covers the entire Sidmouth Arboretum	not stated	Volunteers	Sidmouth Arboretum, 2014
Bridgend (Wales) 2015	4440	A county borough on the south coast of Wales covering five urban areas, including the medium-sized town also named Bridgend	● to gain a better understanding of the urban trees in Bridgend borough ● to value the services, they provide ● to increase the profile of Bridgend's urban trees to ensure its value is maintained and improved	Contractors	Doick et al., 2015a
Tawe Catchment (Wales) 2015	6995	A catchment in South Wales covering eight urban areas including Swansea, the second largest city in Wales	● to gain a better understanding of the urban trees in Tawe Catchment ● to value the services, they provide ● to increase the profile of the urban forest thereby helping to ensure its value is maintained and improved	Contractors	Doick et al., 2015b
Glasgow (Scotland) 2015	17,643	A port city on the River Clyde which is the largest city in Scotland	● to value urban tree benefits as an asset to the community ● to raise the profile of urban trees ● to help protect the urban forest ● to encourage good planning and execution of new urban tree plantings	Contractors	Rumble, Rogers, Doick, & Hutchings, 2015

information were either reports, policies or webpages from local authorities, national government or environmental organisations, as well as scientific articles or conference proceedings. The information from these documents was used to assess the use of i-Tree Eco reports, their impact at both local levels (e.g. new tree policies) and national government and for the wider environmental sector. Some data might have been missed due to its inaccessibility online, as well as that not all local councils have tree management policies (Britt & Johnston, 2008). We therefore aimed to capture more detailed information if, how and why i-Tree Eco outputs were used through the online survey and interviews.

3.2. Online survey of impacts and barriers

The questionnaire was designed to cover the five types of impact by Edwards et al. (2017) and Edwards and Meagher (2019) outlined above. It followed Forest Research's Social and Economic Research Group 'SERG Research Ethics' protocol (SERG, 2010). Survey Monkey (v2017), an online survey cloud-based software tool, was used to create and administer the survey (Denscombe, 2014). The questionnaire included closed and open questions (Appendix 2) and was live from May to October 2017. The organisations and individuals who received the survey invitation and link were identified using a combined purposive snowballing method (Bryman, 2012), using existing professional contacts and online searching. The former included the Arboricultural Association, Local Government Association, Forest Research, Forestry Commission, Greenspace Scotland, Green Infrastructure Partnership, Institute of Chartered Foresters, and the London Tree Officers Association. All agreed to message their members or include the questionnaire link in their newsletter. The questionnaire link was also advertised through Forest Research's Facebook and Twitter accounts, and webpages, and promoted via articles in trade journals targeted at tree and greenspace officers. The individuals contacted were primarily Local Authority tree and greenspace officers, forestry professionals, commercial developers, national government forestry policy makers and those who were involved in i-Tree Eco projects but not interviewed as part of this study.

Fifty-one questionnaire responses were received. The final number available for analysis was 40; the other 11 had only answered the first few questions, i.e. the questions about their role and their organisation but very little else. We are unable to provide a response rate because we don't know how many people received notice or saw the information about our survey or the questionnaire link. Questionnaire respondents were from a wide variety of sectors, encompassing public (local authorities = 8; National Park Authority = 1; other public = 5), private (7) and third sector organisations (5). They were involved in i-Tree Eco projects in various roles, including as project administrator (5), tree surveyor (7), volunteer (4), providing technical support (3), involved in the publication of the project reports (11), and other roles (20). Not all survey respondents provided this information, hence the total of the above does not add up to 40.

3.3. Interviews about impacts, barriers and solutions

To add more in-depth exploration of the experience and opinions of stakeholders, semi-structured interviews (Silverman, 2001) were conducted (Appendix 3), also following SERG Research Ethics protocol (SERG, 2010). Interviewees were identified using the same process as for the online questionnaire. The aim was to find respondents who had been involved in the i-Tree Eco projects and had knowledge of potential impacts achieved during and since their completion. The 18 interview candidates consisted of a cross-section of representatives from local authority (n = 5), regional government (n = 4), third sector (n = 2), private sector (n = 3), and research institutes (n = 4). Interviewees had a range of prior experience with urban trees: some were highly involved in their local urban forest (e.g. local tree officers) while others were more loosely associated (e.g. regional forestry policy officers). However, all interviewees had been involved in at least one of the six case study projects, including in funding, project initiation, project management, or providing technical input. Some had performed multiple roles. Interviews were conducted by telephone between February and August 2017 and lasted for approximately 45 min. With the consent of the interviewees, they were recorded, using a digital voice recorder, and subsequently transcribed in full (Jupp, 2006).

3.4. Data analysis

Data from the online questionnaire were exported directly from Survey Monkey to IBM SPSS v19. Given the number of usable responses, analysis was limited to deriving descriptive statistics (Bryman, 2012). Interview transcriptions were imported and coded in NVivo (V8), a software package designed for analysing qualitative data (Denscombe, 2014). Coding is an interpretive technique used to organise qualitative data and to identify key themes, patterns and relationships (Braun & Clarke, 2006). For this project, a coding framework was designed, based on the interview questions (Silverman, 2001). These provided deductive tier one and two themes. Subsequently, a third tier of themes was added inductively from the additional themes that emerged from the responses of the interviewees. The results are presented in a narrative synthesis (Denscombe, 2014), using tables, figures, and anonymised direct quotes to summarise and illustrate the points being made.

4. Results – impacts

4.1. Instrumental impacts

Results from all six i-Tree Eco case study projects were used to inform at least one report, strategy or policy on topics including climate change, tree pest and disease threats, transport or green infrastructure (for a comprehensive summary see Appendix 4). Two projects used their i-Tree Eco findings to inform new dedicated local tree and woodland strategies. Interviewees stated the importance of the i-Tree Eco project as the evidence base for the policy as well as a driving force to its development: *"That was really the first time we had overarching tree and woodland policies… It would have been hard to do that without i-Tree"*. Results from the interviews suggested that findings from i-Tree Eco projects were also used beyond the local level, to inform regional strategies and national policies, namely a district tree strategy, a regional tree health action plan, a government statement on trees and woodlands, and a reference in the UK National Ecosystem Assessment.

Results from i-Tree Eco projects have also been used in diverse ways to influence practice, processes and debates. The most frequent reported use of i-Tree Eco project results identified in the online survey was to promote the importance of the existing tree resource. A quarter of questionnaire respondents (25%, n = 10) noted that there had been *"a lot"* of change relating to the promotion of the existing tree resource as a result of a local i-Tree Eco project. However, other findings were less positive. Only 3% (n = 1) of the respondents stated that i-Tree Eco had led to *"a lot"* of change in the maintenance or more regular maintenance of trees. Over a third of respondents said there had been no change in tree maintenance (n = 16), expansion of tree planting programmes (n = 15) or help to make a case for new staff (n = 14) or keep existing tree officers (n = 13) due to the i-Tree Eco project (Fig. 2).

Examples described by the interviewees for the use of the i-Tree Eco project results were linked to the use of data by a specific group or for a particular purpose, including helping Swansea (Tawe Catchment) to inform tree species selection and priority areas for new planting; by Devon Ash Resilience Forum to support monitoring and management of diseased trees; the Task and Finishing Forum within a council to support tree maintenance; by local authority tree officers and advisors to build a case for a broader approach to tree management for wider

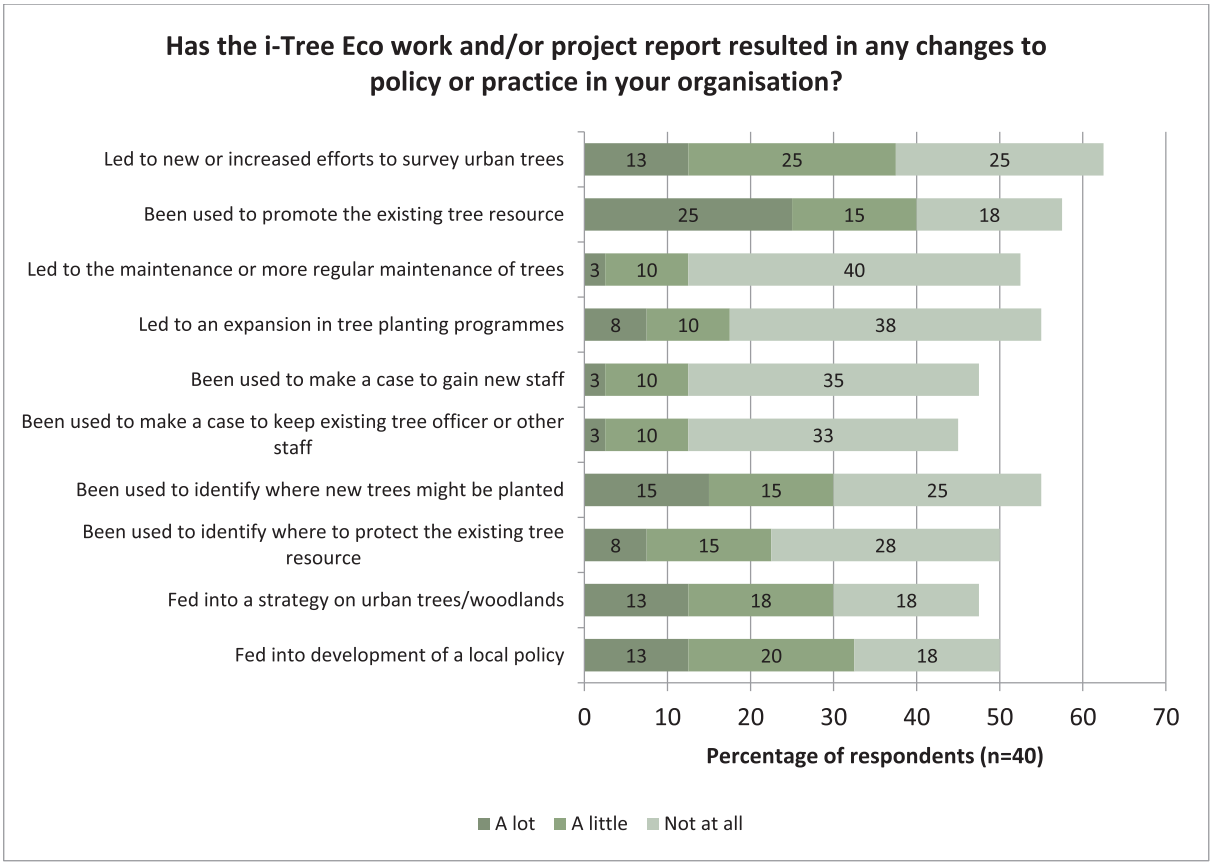


Fig. 2. Reported changes in policy and practice resulting from i-Tree Eco projects.

public benefits; and by one council to set climate change adaptation targets.

In terms of funding, 20% of the online respondents (n = 8) reported that the i-Tree Eco project, which they knew about or had been involved in, had led to themselves or others being able to secure funding to expand the urban tree resource. The results from the interviews provided two specific examples where i-Tree Eco appeared to have led to new investment into new projects run by external organisations: a tree planting initiative in Edinburgh and an i-Tree trail in Torbay. In two other cases, it was felt that the i-Tree Eco work had led to the preservation of budgets during a period when many department budgets were being cut. One interviewee noted that there might have been greater positive impact on budgets for urban tree management if the i-Tree Eco surveys had been carried out before the recession in 2008.

4.2. Conceptual impacts

The online questionnaire results revealed that 60% (n = 31) of the respondents had a better understanding of the importance of trees in urban areas, and more knowledge about the urban tree resource because of the i-Tree Eco survey. The three main areas where personal understanding had increased were: a) the importance of the urban tree resource in general, b) the species composition mix of the urban tree resource, and c) the importance of trees in the removal of urban air pollution (Fig. 3).

Although little change to attitudes was reported by the interviewees, respondents noted conceptual impact occurred through reported increases in knowledge, understanding and awareness. Interviewees felt they personally developed understanding of the local *"tree population"* and *"which trees should be planted"*. i-Tree Eco projects also increased understanding of broader topics, such as the importance of urban trees, their value and the ecosystem services they provide: *"I certainly understand more about how important urban trees are."* Another interviewee explained that *"Five years ago I hadn't any grasp of the value of trees, in terms of ecosystem service provision… so it's been a real eye opener and really powerful."* Two interviewees stressed that they already worked in the sector, and so already knew the importance of trees. However, the results suggested that interviewees were aware of or believed that i-Tree Eco had also increased understanding by other people, especially the general public's understanding of trees and tree diseases, links to climate change and the environment in a wider sense, and the social benefits of trees.

4.3. Capacity-building impacts

The online questionnaire results establish that 60% (n = 24) of the respondents felt that involvement in i-Tree Eco work had increased either their capacity, or the capacity of their colleagues, or other stakeholders. For example, 40% (n = 16) said that they now know where to look for more information on the results of i-Tree Eco projects. The interview results regarding development of skills and expertise were mixed. One interviewee reported that there were approximately 15 people who carried out data collection for the i-Tree Eco survey in their area. As none of them had undertaken a tree survey before, they all learnt basic surveying and tree identification skills. However, this case was unique in its use of volunteers, while others used contractors who would already have had this knowledge (Table 1). Another interviewee explained that having to pull together an i-Tree Eco project with colleagues involved understanding the methodology, the software package, being able to train people, such as volunteers, and fundraising to make it happen. However, other interviewees felt that involvement in the i-Tree Eco work had not increased the respondents or others' skills or expertise. One interviewee, for instance, stated: "*I don't really know what skills you get from i-Tree Eco*".

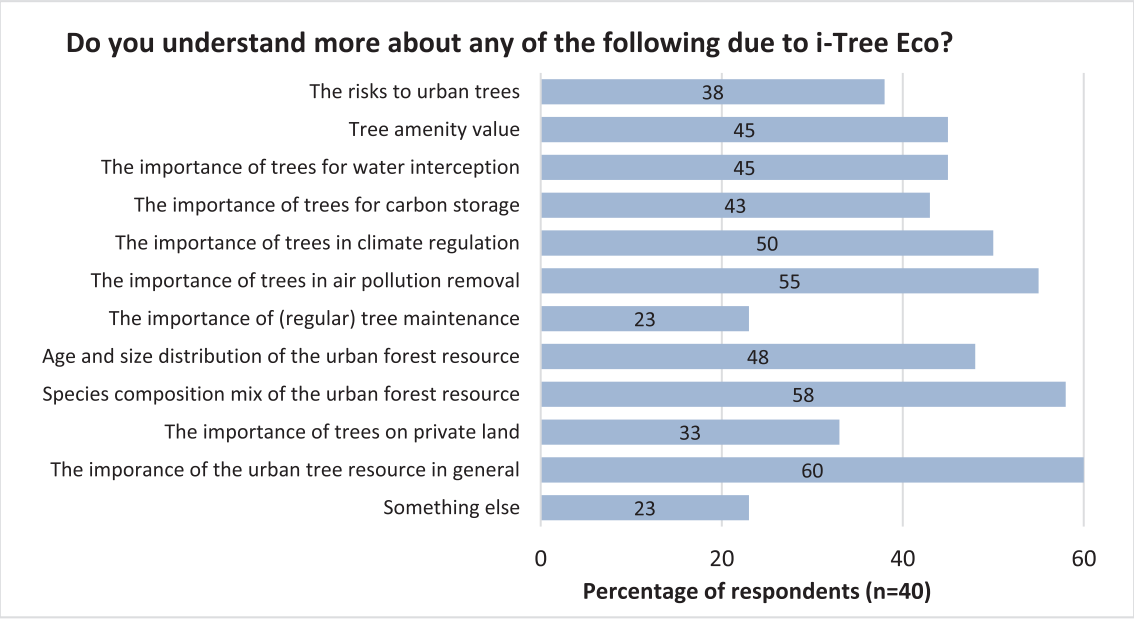


Fig. 3. Understanding of urban tree resource resulting from i-Tree Eco projects.

The i-Tree Eco case studies showed that many users of the i-Tree Eco data said having the 'facts' on the state and benefits of trees put them in a better position, and gave them confidence, to make the case for urban forests; policy-makers felt more able to brief higher-level officers; tree officers had more robust data to justify their decisions, and community groups had the confidence to speak with greater authority on urban forest management.

4.4. Enduring connectivity impact

Thirty eight percent (n = 15) of the online survey respondents said that the i-Tree Eco projects had led to new engagement between different parts of their organisation (15% = a lot; 23% = a little). Furthermore, 38% (n = 15) indicated that new collaborations, specifically links to researchers, had then generated conceptual impacts, by helping users to understand the i-Tree Eco results (13% = a lot; 25% = a little).

The interviews revealed several examples of new or increased collaboration within and between organisations as a result of involvement in i-Tree Eco work, including:

- Between teams and departments within local authorities, such as climate change adaptation teams, transport and planning departments and sustainability units
- Between sectors such as private businesses, the health sector, universities, schools, local environment interest groups, and specific organisations such as Areas of Outstanding Natural Beauty (AONBs), the Highways Agency, and Forest Research (public sector research institute in GB).

While valuable as an impact in its own right, the improved connectivity within organisations helped to generate further conceptual impacts, e.g. greater interest in trees across a wider range of council departments. The results from the interviews also showed that two i-Tree Eco projects used workshops to discuss results with a wide range of stakeholders and found these helped improve engagement with the projects. In one of these cases this helped to foster collaboration between tree teams and other council departments, especially planning, where i-Tree Eco was useful to help unlock conversations and led to the co-production of a green infrastructure strategy. This, in turn, prompted positive changes in the fifth category of impact, i.e. culture/attitudes towards knowledge exchange. As one interviewee put it, "*I would say it's* [involvement in i-Tree Eco] *reinforced our* [positive] *attitude to collaboration*."

4.5. Culture/attitudes towards knowledge exchange impacts

The study results offer several examples of changes to culture/attitudes towards knowledge exchange (see Appendix 4 for a comprehensive summary). Some interviewees found that dissemination had not always been successfully planned and delivered, and that many projects, especially earlier i-Tree Eco projects, started without a clear idea of the audience for the project findings. These experiences often changed attitudes towards knowledge exchange, with evidence of learning across the i-Tree Eco stakeholders on how to improve dissemination and hence impact. One interviewee, for example, explained that the i-Tree Eco study "*improved my understanding of the process, and the limitations … the difficulties of gathering meaningful data, and then how to present that data in a way that will influence policy making and resource allocation*". As a result, some projects evolved their approach to reporting and began to deliver accessible research summaries of two to four pages with infographics as well as technical report targeting those working closely with trees.

One interviewed project commissioner reported learning that effective uptake requires pre-project planning, not just post-project dissemination. Others had learned to appreciate the time required for effective knowledge exchange. In another case, the project team decided to set up a steering group with representation from across the local authority. They established a major launch meeting beforehand, and a workshop after completion of the survey, both with diverse stakeholders, "*to disseminate the results and to start action planning knowing what the results were.*" In all these cases, changes in individual attitudes represent lessons learned about how to enhance impact, and hint at the possibility of enduring changes in culture within a department or team.

5. Results – barriers to impact and solutions

The impact evaluation study also explored barriers that may have reduced impacts of the i-Tree Eco projects. Online survey respondents were asked to rate the importance of a range of potential barriers. Lack of funding to promote the work was listed as very important (23%, n = 9), followed by a lack of high-level endorsement within their

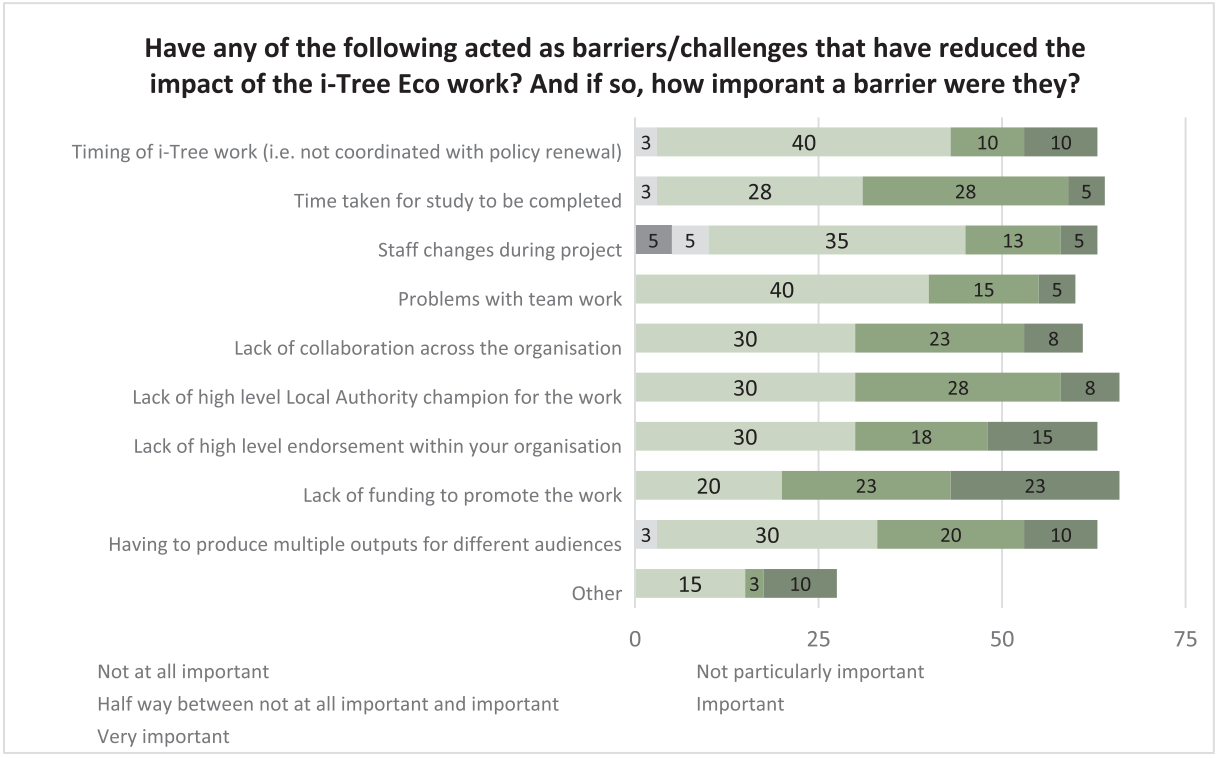


Fig. 4. Barriers to impact of i-Tree Eco projects.

organisation (15%, n = 6) (Fig. 4). The time taken to undertake an i-Tree Eco project (23%, n = 9), the lack of a high level i-Tree Eco project champion (28%, n = 11), and the lack of engagement across different local authority departments (23%, n = 9) were also seen as important barriers to impact. Staff changes, problems within the i-Tree project delivery team, and the timing of the i-Tree Eco project, i.e. in relation to, for example planned policy updates or changes, were somewhere in between very import and not at all important. Several survey respondents (28%, n = 11) reported additional barriers under 'others', including the "*cost of undertaking the works*", *the "lack of resources in the commissioning team",* that "*i-Tree Eco had been run in parallel to (rather than being part of) other tree assessments*", a lack of follow on activities after the publication of the report, the challenge in quantifying ecosystem services, and a "*lack of spatial resolution*" to support data interpretation at the pan-city scale.

5.1. Insufficient knowledge exchange and transfer

The interviews provided greater insights, identifying a range of barriers and solutions. Knowledge exchange, communication and dissemination of the findings were frequently highlighted as areas that had not always been successfully planned and delivered. These issues were also seen to be related to: a lack of clarity about who was the audience; insufficient resources available for dissemination; a lack, within project teams, of the skills and resources needed for effective knowledge exchange, and a failure to produce outputs appropriate for different audiences and levels of technical understanding. Overall, there was evidence to suggest that projects with a clear aim on how to use the i-Tree Eco study data followed through with new policy creation; while others without or whose plans were derailed by loss of their project champion, for example, appeared to lose direction in terms of how to apply the results after publication.

5.2. Context

Several barriers were reported regarding aspects of the user context. Interviewees suggested that some people, including both professionals and the general public, have negative opinions about trees in urban areas, which can be perceived as nuisances (such as blocking light) or risking injury to the public (from falling trees or branches). Other concerns related to leaves on the ground, maintenance, and interference with cables. One commented that highway engineers, amongst others, "*still all see trees as really a problem they could do without*". In some cases, i-Tree Eco had helped to overcome this negative perception. One interviewee suggested that "[it is] *my job to try and get resources for urban trees …. and for a long time, I succeeded in getting resource by selling risk. That only takes you so far, you really have to sell value, what i-Tree does is it helps to balance [the] equation to say….. You've got to say we need to plant trees because … they benefit capital values, they stop pollution, etc."*

5.3. Lack of high-level endorsement

The lack of senior buy-in or a high-level champion for the i-Tree Eco projects was often mentioned. In some cases, the original 'champion' was not a senior member of staff but someone working at the level where staff turnover was generally higher, increasing the risk that they move on before the project reaches completion. There was an awareness that the information within an i-Tree Eco report needs to be passed on, especially by senior champions and used by service areas within councils, including highways, health and sustainable urban drainage teams. However, one respondent said that that this would require other departments to have *"a different mind-set to want to deliver their objectives through green infrastructure".*

5.4. Insufficient policy drivers

Other interviewees noted that there were insufficient policy drivers requiring local authorities to fund new tree and woodland interventions. Some departments were unable to act on the information, as they needed to operate within their existing policy guidelines, which did not see a role for trees: "*It's not that they don't want to use it [i-Tree results].*

It's just they can only do what they have in their policies." One interviewee felt that the creation of a top-down driver was not going to happen and suggested a 'bottom-up' approach through support to community groups to run and apply i-Tree Eco projects would generate greater change.

5.5. Lack of resources

Lack of funding and time to carry out projects to the full extent, including the dissemination of the findings to internal and external stakeholders, and to implement the recommendations that were made, was frequently reported. One project could not fully analyse their results, while another did not have time to promote results widely. Lack of funding was seen by interviewees to be a consequence of the low priority given to trees, noted above, but also cutbacks in the sector, coupled with organisational restructuring, causing councils and other public bodies to focus on priorities such as education, social care, and health. In the words of one respondent: "*There's been a reduction in staff as a whole across the local authority. People, the key working links that were there before, don't exist anymore. Whole structures have changed …".*

5.6. Scope and outputs

The study highlighted an additional barrier, namely the relevance of, or satisfaction with, the i-Tree Eco tool's current scope and outputs from the perspective of potential users. Several interviewees mentioned that some professionals raised concerns about the accuracy of the quantifications of tree benefit outputs. Interview respondents also mentioned that the tool would have been more useful if it provided data on trees' social benefits, especially physical and mental health, but also aesthetic value, the benefits of noise abatement, and estimates of the annual cost to maintain the reported flow of benefits, which would make the findings more policy relevant.

6. Discussion

Our evaluation of the impacts of multiple i-Tree Eco projects on the management and protection of urban forests raises several issues of relevance to other researchers developing and implementing i-Tree Eco and other decision support tools. These include issues linked to the type of reported impacts, barriers and challenges to impact, and to key lessons learned.

6.1. Type of impacts of i-Tree Eco

As noted in the introduction, environmental decision support tools are rarely utilised to the extent originally anticipated, despite a shared perception among researchers and end-users that a tool would provide useful knowledge for decision support (Schröter et al., 2016; Stewart et al., 2013). Nevertheless, our evaluation of multiple i-Tree Eco projects provided convincing examples of all five impact types used for the purpose of this analysis, including direct instrumental impacts on policies, strategies at local authority level, and the decisions that they influence regarding urban tree management. The breadth of impact types considered in this impact evaluation enabled a broad and deep reflection of the impacts of i-Tree Eco projects in the UK. The degree of impact delivered varied between projects. Instrumental impact tends to be seen as the most desirable change resulting from a research, assessment or evaluation project (Nutley et al., 2007) and this was also the case amongst the i-Tree Eco stakeholders. However, across research discplines, it appears to be less common than one might hope for or anticipate (Meagher, 2012; Ruckelshaus et al., 2015). Similarly, we should not necessarily expect i-Tree Eco projects to generate direct instrumental impacts on decisions in all cases, especially not in the short term.

Often it is necessary first to change how people think and feel about an issue, i.e. conceptual impact, or build their capacity or connectivity, or influence their attitudes towards knowledge exchange, before, perhaps at a later date and in a different decision-making arena, instrumental impacts arise that may not have been predicted. Thus, it has been argued that changes in thinking are a crucial first step to greater impact, as decision-makers must first understand and value the resource or ecosystem, in this case the urban tree resource, in order to drive change (Ruckelshaus et al., 2015). Similarly, Meagher et al. (2008) suggest that changes in policy or practice often stem from a general 'awareness-raising' or conceptual shift, this being the first step in a process toward impact. Having said that, Edwards and Meagher (2019) note that the order in which the five impact types unfold over time can happen in multiple ways, due to the range of actors who need to be influenced along diverse impact pathways through research, policy and practice. As knowledge transfer tends to be non-linear (Stewart et al., 2013), and new scientific evidence may question or modify existing knowledge or bring up new uncertainties, environmental policy and practice may have to be adjusted over time. Clear and tailored communication of scientific findings and the uncertainties frequently associated with them is therefore crucial to inform effective policy (Whitlow et al., 2014) and practice. It will "increase decision-maker's confidence of scientific results and improve the quality of decisions" (Holnicki & Nahorski, 2015: 596).

In recent years, there has also been a realisation that traditional 'knowledge transfer' is insufficient, and that interaction is a fundamental requirement for impact generation, requiring ongoing engagement with users (Morton, 2015b). Concurrent with the increasing demand for evidence of impacts has been the movement away from a linear, uni-directional concept of 'knowledge transfer' towards a more complex and dynamic notion of knowledge exchange, whereby knowledge is the result of social and political processes, and uptake is a function of effective relationships and interaction (Stewart et al., 2013). Both researchers and stakeholders can be seen to have important knowledge that should be shared "through feedback loops and interactions, such as informal relationships, joint framing of research questions or co-production of knowledge" (Edwards & Meagher, 2019). Engaging early with key stakeholder groups, for example, may help foster collaboration between local authority tree teams and other council departments, especially when trying to implement and/or make use of the findings, as observed in two of our case studies. Reed, Bryce, and Machen (2018) also suggest that the involvement of "well-trusted", "centrally-positioned" individuals, and of "boundary organisations" in the development of policy relevant research can be crucial to enhance its credibility and confident utilisation. Such co-development and/or co-production of environmental research projects can help to overcome barriers to impact (Reed, 2018).

6.2. Barriers and challenges to impact

The main barriers to impact reported by our i-Tree Eco impact evaluation concerned 'dissemination' and 'engagement', and issues associated with 'users' including aspects of their governance, capacity and culture. These barriers are in line with expectations from related studies (Morton, 2015b; Posner et al., 2016; Stewart et al., 2013). For example, a review of the UK NEA identified the reason for the lack of (instrumental) impact as the lack of identifying an audience and then producing a report whose content and style provided the information decision-makers needed to take it forward (Waylen & Young, 2014). In the case of our i-Tree Eco case studies, it was often the lack of resources to produce tailored outputs which caused a barrier to impact. The lack of engagement is now well established in the literature as another key barrier for the uptake, utilisation and impact of research (Reed, 2018; Sabatier & Jenkins-Smith, 1993). This, however, also requires more resources from the outset.

The underlying barrier restricting the impact of i-Tree Eco is arguably the low importance attached to the management of urban trees. As

mentioned in the introduction, the approach of local governments to urban forest management has been described as risk-averse and lacking strategic, long-term planning, where potential for tree damage to buildings and safety risks drive local authorities to manage trees (Britt & Johnston, 2008; Davies et al., 2017b). To some extent this problem can be addressed by the outputs of the tool itself as it helps to provide a greater appreciation of benefits provided by urban trees (Nowak et al., 2008; Willis & Petrokofsky, 2017). In fact, our study found that i-Tree Eco projects helped to counter negative arguments against trees by highlighting the positive contributions of urban trees.

As noted in Section 5, feedback was also provided about the relevance of, or satisfaction with, the tool's scope and outputs, specifically the range of ecosystem services it was able to value, the values it elicits, and the quality of the quantitative data it produces. Although, the quantitative approach provided by i-Tree Eco can be powerful for decision-making, for example when making the case for budget allocations for tree planting and maintenance (Andrew & Slater, 2014), the small number of services that can be credibly quantified in this way could be seen as a barrier to impact. This, however, is a general problem with valuations, since many ecosystem services, especially cultural/social services are difficult to quantify and monetize meaningfully (Irvine et al., 2016; O'Brien et al., 2017). One way of overcoming this, and thus to enhance impact, would be to complement the findings of i-Tree Eco with qualitative assessments as part of a longer process of engagement with users that addresses a wider range of user needs. A similar point is made by Ozdemiroglu and Hails (2016) who recommend that economic value evidence is presented as part of a three-stage process alongside quantitative and qualitative assessments. Studies which assessed the performance of computer-based models, for instance, carbon sequestration measurements (Boukili et al., 2017) and air pollutant models (Holnicki & Nahorski, 2015; Whitlow et al., 2014) also questioned the reliability of the data produced by these models. Our findings indicate that this can lead to a lack of trust in the data produced by such tools. Policy-, decision-makers, and managers need to be aware of these imperfections and realise that available models can produce different estimates when used in different locations (Boukili et al., 2017). A more complete coverage of the full range of ecosystem services, and a more inclusive, mixed methods approach to their valuation, could help to overcome these barriers and make ecosystem assessments, such as i-Tree Eco, and the quantities and values these elicit, more accepted, relevant and routinely incorporated into decision-making.

6.3. Limitations and key lessons

There are also a number of limitations with this study. First, given the relatively small sample of the online survey, those results need to be seen as indicative. In relation to the interviews, the sample was deliberatively selective, to include those who had been closely involved with the six case study i-Tree projects. Nevertheless, contextual understanding is achieved through examination of the quantitative data alongside and in-light of the qualitative data from the interviews, providing new insights into the impacts created by these i-Tree Eco projects. Second, whilst application of the i-Tree Eco tool per se is not research, it does involve field surveying and interpretation of data (Nowak et al., 2018). There are, therefore, close parallels to research practice and dissemination and the use of an evaluation framework designed for research impact, as opposed to a generic logical framework for programme evaluation, ensured focus on a relevant range of impact types. Thirdly, it is important to note that the impact category 'culture/attitudes towards knowledge exchange' was, at times, misinterpreted as a requirement for respondents to report on their engagement activities or changes in attitudes towards trees in general, rather than a realisation, resulting from the project, that traditional 'knowledge transfer' is insuffient, and that interaction is a fundamental requirement for impact generation, requiring action to make it happen (Edwards & Meagher, 2019).

Most of the barriers outlined in Section 5 can be reinterpreted as both lessons learned and recommendations for the future. Drawing on these, we have identified eight lessons to enhance the impact of future i-Tree Eco projects or other assessment and valuation projects and tools:

1. *Problem framing:* have a clear aim and negotiate with potential users a shared vision regarding desired changes to management, policy, knowledge, attitudes, capacity and/or connectivity.
2. *Management:* understand roles and responsibilities both within and beyond the project team, e.g. volunteers, users, champions and other knowledge intermediaries.
3. *Inputs:* be realistic about the resources needed for analysis, reporting, engagement and dissemination, acknowledging that impact generation takes time and might require actions beyond immediate delivery of outputs.
4. *Outputs:* ensure the content of outputs meets user needs, e.g. existing policy agendas.
5. *Engagement:* encourage stakeholder engagement from the start, e.g. through co-development and production of the assessment, and during the production and dissemination of outputs.
6. *Dissemination:* tailor the format of project outputs carefully for each respective audience, e.g. by ensuring they contribute to existing planning procedures.
7. *Users:* seek to engage 'champions' within the potential user communities who will help promote the project and specific findings, either informally or through formal user groups.
8. *Context:* Prepare for and respond proactively to contingent factors such as reorganisations, public sector budget cuts, staff turnover and changes in priorities, e.g. by generating support and understanding from a range of potential users.

7. Conclusion

This paper represents the first published impact evaluation of multiple i-Tree Eco projects. Our findings demonstrate that combined ecosystem assessment and valuation tools like i-Tree Eco can support environmental decision-makers and managers. We show that i-Tree Eco provides a broad assessment of the urban forest and its composition, structure and condition – especially at the local level, and usually for the first time. By quantifying and valuing key ecosystem services, it can help inform management decisions, such as tree species selection, and strengthen the case for investment in urban forests. This combined approach can be particularly valuable, if carefully used and communicated, as it addresses the needs of different users at the same time. At a conceptual level, the tool can improve the understanding and appreciation of the importance of urban trees and woodlands among diverse stakeholders, including local authorities, the public and non-governmental organisations. In fact, the i-Tree Eco projects have helped change the framing of trees in local governments from a focus on their costs and liability, to their value and benefits. This change in appreciation, or the building of capacity or connectivity in form of engagement are often the first steps in a longer-term process before instrumental impacts arise.

The creation of impact can be complex and convoluted, and for this reason we used an evaluation framework that helps to make the process of impact generation more explicit. In doing so, we show learning that supports claims for greater emphasis on quality engagement between research, policy and decision-making to realise the benefits latent in projects such as these, and in the use of similar decision-making tools. The evaluation also explored barriers to uptake, and hence the pitfalls in seeing the i-Tree Eco tool as a 'silver bullet'. However, if following our eight lessons outlined above, the impact of future i-Tree Eco projects or other assessment and valuation projects and tools can be considerably enhanced, and routinely offer the necessary evidence, in the right format, to be used directly to improve environmental policy and

management. We also suggest conducting a meta-analysis of the results of all i-Tree Eco studies as well as a GB wide analysis of multiple urban forestry inventory data arising from i-Tree Eco studies to inform national urban forestry and green infrastructure strategy. Such studies could help inform delivery of multiple policy objectives from climate change adaptation to increasing resilience. We have argued that the key lessons learned from the evaluation reported here reflect the findings of recent literature on the uptake and utilisation of research knowledge, and that our findings and recommendations provide insights that can usefully inform other assessment and valuation projects.

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Appendix 1. Documentary review

Torbay, England (2010)

Before i-Tree Eco project	After i-Tree Eco project
i-Tree Eco reports	
	• Rogers, K., Jarratt, T. & Hansford. D. (2011a). Torbay's Urban Forest. Assessing urban forest effects and values. A report on the findings from the UK i-Tree Eco pilot project. Treeconomics, Exeter.
National government	
	• Watson, R., Albon, S., Aspinall, R., Austen, M., Bardgett, B., Bateman, I., … & Bulloch, J. (2011). UK National Ecosystem Assessment: Technical Report. United Nations Environment Programme World Conservation Monitoring Centre.
Local government – tree policies and reports	
• East Devon District Council (2005). Trees and Development. Supplementary Planning Guidance. East Devon District Council. Knowle, Sidmouth, UK.	• Wolton, R. (2016). Devon ash dieback action plan. Report for Devon Local Nature Partnership and Devon Hedge Group. • Torbay Council (2013). A Tree and Woodland Framework for Torbay 2012 – 2017. Torbay Council. Torbay, Devon, England.
Local government – other policies and reports	
• Torbay Council (2008). A Climate Change Strategy for Torbay 2008–2013. Torbay Council. Torbay, Devon, England. • Torbay Biodiversity Steering Group (2006). The Nature of Torbay: A Local Biodiversity and Geodiversity Action Plan 2006–2016. Torbay Council.	• Torbay Council (2014). Torbay Energy and Climate Change Strategy 2014–2019. Torbay Council. Torbay, Devon, England.
Environmental organisations	
	• Landscape institute & Town and Country Planning Association (2012). Green Infrastructure Scoping Study WC0809. Report for DEFRA. • Woodland Trust (2015). The economic benefits of woodland. Report by Europe Economics for the Woodland Trust. Woodland Trust, Grantham, UK. • The Tree Council (2015). Chalara in Non-Woodland Situations. Findings from a 2014 Study. Report undertaken by the Tree Council on behalf of Defra.
Scientific outputs	
	• Rogers, K., Hansford, D., Sunderland, T., Brunt, A., & Coish, N. (2011). Measuring the ecosystem services of Torbay's trees: the Torbay i-Tree Eco pilot project. Trees, people and the built environment. Conference Proceedings. • Sunderland, T., Rogers, K., & Coish, N. (2012). What proportion of the costs of urban trees can be justified by the carbon sequestration and air-quality benefits they provide? Arboricultural Journal, 34(2), 62–82. • Rumble, H., Rogers, K., Doick, K., & Hutchings, T. (2014). A comparison of Urban Tree Populations within Four UK Towns and Cities. Presented at Trees, People and the Built Environment, April 2014.

Edinburgh, Scotland (2011)

Before i-Tree Eco project	After i-Tree Eco project
i-Tree Eco reports	
	• Hutchings, T., Lawrence, V., & Brunt, A. (2012). Estimating the Ecosystem Services Value of Edinburgh's Trees. Forest Research. • Doick, K.J., Handley, P., Ashwood, F., Vaz Monteiro, M., Frediani, K. & Rogers, K. (2017). Valuing Edinburgh's Urban Trees. An update to the 2011 i-Tree Eco survey – a report of Edinburgh City Council and Forestry Commission Scotland. Forest Research, Farnham.
National government	
Local government – tree policies and reports	
• Urban Forestry Strategy for Edinburgh (1991) • Trees in the City: Trees and Woodlands Action Plan – January 2014. City of Edinburgh Council. Edinburgh, Scotland.	• Lothians and Fife Green Network Partnership (2012). Edinburgh and Lothians Forestry and Woodland Strategy. City of Edinburgh Council. Edinburgh. • City of Edinburgh Council (2014). Trees in the City: Trees and Woodlands Action Plan – January 2014. City of Edinburgh Council. Edinburgh, Scotland.
Local government – other policies and reports	
• City of Edinburgh Council (2008). Air Quality: Action Plan (Revised 2008). City of Edinburgh Council. Edinburgh, Scotland.	• City of Edinburgh Council (2013). Consultation on the Draft Scottish Climate Change Adaptation Programme. City of Edinburgh Council. Edinburgh, Scotland.

• City of Edinburgh Council (no date). Edinburgh's Environment: state of the Environment Audit: Trees and Woodlands. City of Edinburgh Council. Edinburgh, Scotland.	
Environmental organisations – policies, reports or webpages	
	• Scottish Forum on Natural Capital (2014). Edinburgh sets Natural Capital Example. Available online at: http://naturalcapitalscotland.com/article/edinburgh-sets-natural-capital-example/ • The Tree Council (2015). Chalara in Non-Woodland Situations. Findings from a 2014 Study. Report undertaken by the Tree Council on behalf of Defra. • TreeTime Edinburgh (2017). Website available at: http://www.tree-time.com/
Scientific outputs	
	• Rumble, H., Rogers, K., Doick, K., & Hutchings, T. (2014). A comparison of Urban Tree Populations within Four UK Towns and Cities. Presented at Trees, People and the Built Environment, April 2014.

Glasgow, Scotland (2013)

Before i-Tree Eco project	After i-Tree Eco project
i-Tree Eco reports	
	• Rumble, H., Rogers, K., Doick, K., Albertini, A., & Hutchings, T. (2015). Assessing the Ecosystem Services of Glasgow's Urban Forest: A Technical Report. Forest Research, Farnham.
National government	
Local government – tree policies and reports	
• Land Use Consultants (2011). Glasgow and Clyde Valley Forestry and Woodland Strategy. Environment Report. Prepared for Glasgow and Clyde Valley Strategic Development Authority. Glasgow City Council. Glasgow, Scotland.	
Local government – other policies and reports	
• Glasgow City Council (2004). Glasgow Parks and Open Spaces: Strategic Best Value Review and Implementation Plan. Glasgow City Council. Glasgow, Scotland. • Glasgow Clyde Valley Green Network Partnership (GCVGNP; 2013). Green Infrastructure for Overheating Adaptation in Glasgow. Report for GCVGNP by Glasgow Caledonian University. • Glasgow City Council (2009). Air Quality Action Plan. Glasgow City Council. Glasgow, Scotland.	• Glasgow City Council (2016). Public Sector Climate Change Duties 2016 Summary Report – Glasgow City Council. Glasgow City Council. Glasgow, Scotland. • Glasgow City Council (2017). SG7: Natural Environment. Supplementary Guidance. Glasgow City Council. Glasgow, Scotland. • Glasgow City Council (2014). Energy and Carbon Masterplan. Sustainable Glasgow. Glasgow City Council. Glasgow, Scotland.
Environmental organisations	
	• The Tree Council (2015). Chalara in Non-Woodland Situations. Findings from a 2014 Study. Report undertaken by the Tree Council on behalf of Defra.
Scientific outputs	
	• Rumble, H., Rogers, K., Doick, K., & Hutchings, T. (2014). A comparison of Urban Tree Populations within Four UK Towns and Cities. Presented at Trees, People and the Built Environment, April 2014.

Bridgend, Wales (2014)

Before i-Tree Eco project	After i-Tree Eco project
i-Tree Eco reports	
	• Doick, K. Albertini, A., Handley, P., Lawrence, V., Rogers, K., & Rumble, H. (2015a). Valuing the Urban Trees in Bridgend County Borough. Technical Report. Forest Research in Association with Natural Resources Wales and Bridgend County Borough Council. • NRW (2016). Bridgend's Urban Trees – an amazing resource benefiting us all. Natural Resources Wales.
National government	
• NRW (2014). Tree Cover in Wales' Towns and Cities: Understanding canopy cover to better plan and manage our urban trees. Natural Resources Wales. Aberystwyth, Wales.	
Local government – tree policies and reports	
• BCBC (Bridgend County Borough Council). (2007). Trees and Development SPG 07. Bridgend County Borough Council. Bridgend, Wales.	
Local government – other policies and reports	
• BCBC (2012). Bridgend Local Development Plan 2006–2021 (2012 revision). Bridgend County Borough Council. Bridgend, Wales. • BCBC (2014). Bridgend County Borough Local Biodiversity Action Plan: Biodiversity and Ecosystem Services Assessment and Revision 2014. Bridgend County Borough Council. Bridgend, Wales.	• BCBC (2015). Local Transport Plan 2015–2030. Bridgend County Borough Council. Bridgend, Wales. • BCBC (2016). Bridgend Local Development Plan: Annual Monitoring Report 2016. Bridgend County Borough Council. Bridgend, Wales. • Wythenshawe (2016). Social Impact Methodology. Wythenshawe Community Housing Group. Manchester, England.
Environmental organisations	
	• Wildlife Trusts Wales (2016a). Green Infrastructure: A Catalyst For the Well-being of Future Generations In Wales. Wildlife Trusts Wales.
Scientific outputs	

Sidmouth (2014)

Before i-Tree Eco project	After i-Tree Eco project
i-Tree Eco reports	
	• Sidmouth Arboretum (2014). Sidmouth Arboretum Tree Survey. Sidmouth Arboretum. Sidmouth, UK.
National government	
Local government – tree policies and reports	
• EDDC (2005). Trees and Development. Supplementary Planning Guidance. East Devon District Council. Knowle, Sidmouth, UK.	
Local government – other policies and reports	
• EDDC (2012). East Devon Open Space Study. Final report prepared by Bennett Leisure and Planning Ltd, and JPC Strategic Planning and Leisure Ltd. East Devon District Council. Knowle, Sidmouth, UK.	
• EDDC (2016). East Devon Local Plan 2013–2031. East Devon District Council. Knowle, Sidmouth, UK.	
Environmental organisations	
	• Wolton, R. (2016). Devon ash dieback action plan. Report for Devon Local Nature Partnership and Devon Hedge Group.
Scientific outputs	

Tawe Catchment, Wales, 2014

Before i-Tree Eco project	After i-Tree Eco project
i-Tree Eco reports	
	• Doick, K. Albertini, A., Handley, P., Lawrence, V., Rogers, K., & Rumble, H. (2016). Valuing Urban Trees in the Tawe Catchment. Technical Report. Forest Research.
	• NRW (2016). Swansea and Tawe's Urban Trees – an amazing resource benefiting us all. Natural Resources Wales.
National government	
• NRW (2014). Tree Cover in Wales' Towns and Cities: Understanding canopy cover to better plan and manage our urban trees. Natural Resources Wales. Aberystwyth, Wales.	
Local government – tree policies and reports	
	• CCS (2016a). Tree Policy for Council Owned Trees. City and County of Swansea. Swansea, Wales.
	• CCS (2016a). Letter from the Tree Preservation Scrutiny Working Group to the Cabinet Member for Enterprise, Development & Regeneration. Tree Preservation Scrutiny Working Group. City & County of Swansea. Swansea, Wales.
	• CCS (2016d). The Protection of Trees on Development Sites. Supplementary Planning Guidance. City and County of Swansea. Swansea, Wales.
Local government – other policies and reports	
• CCS (2008). Unitary Development Plan (UDP). City and County of Swansea. Swansea, Wales.	• CCS (2016b). Green Infrastructure. Local Development Plan Topic Paper. City & County of Swansea. Swansea, Wales.
• NPTCBC (2012). Air Quality Action Plan. Neath Port Talbot County Borough Council. Port Talbot, Wales.	• Powys County Council (2015a). Local Development Plan (Draft). Powys County Council. Llandrindod Wells, Wales.
• NPTCBC (2008). Environment Strategy. Neath Port Talbot County Borough Council. Port Talbot, Wales.	• Powys County Council (2015b). Natural Heritage. Local Development Plan Topic Paper. Powys County Council. Llandrindod Wells, Wales.
• Swansea Environmental Forum (2014). Swansea Environment Strategy. Action Plan 2014–16. Swansea, Wales.	• NPTCBC (2016a). Local Development Plan (2011–2026). Neath Port Talbot County Borough Council. Port Talbot, Wales.
	• NPTCBC (2016b). Pollution. Supplementary Planning Guidance. Neath Port Talbot County Borough Council. Port Talbot, Wales.
	• NPTCBC (2017a). Open Space and Greenspace. Supplementary Planning Guidance. Neath Port Talbot County Borough Council. Port Talbot, Wales.
	• NPTCBC (2017b). Design. Supplementary Planning Guidance. Neath Port Talbot County Borough Council. Port Talbot, Wales.
Environmental organisations	
	• Wildlife Trusts Wales (2016). Wildlife Trusts Wales response to: Local air quality and noise management in Wales. Wildlife Trusts Wales. Cardiff, Wales.
	• Wythenshawe (2016). Social Impact Methodology. Wythenshawe Community Housing Group. Manchester, England.
Scientific outputs	

Appendix 2. Question headings in the online questionnaire

- Which organisation do you work for?
- What is your role within the organisation?
- When did you first hear about i-Tree Eco?
- How did you first hear about i-Tree Eco?
- Which i-Tree Eco project have you been involved with or heard about?
- If you got involved in i-Tree Eco – how did that happen?

1. Conceptual:

- Which findings of the i-Tree Eco project do you think are or would be most useful to you and your organisation?
- Do you feel there has been any change in your understanding and attitudes about urban trees and the values they provide to society due to i-Tree

Eco?
- Are you aware of any changes in understanding, attitudes, actions in your organisation about the urban tree resource and its value due to i-Tree Eco?
- Are you aware of any changes in understanding, attitudes, actions among others outside of your organisation about the urban tree resource and its value due to i-Tree Eco?

2. Instrumental:

- Has undertaking the i-Tree Eco work and/or the production of the i-Tree Eco project report resulted in any changes to policy or practice that you are aware of in your organisation?

3. Capacity-building:

- Has involvement in i-Tree Eco increased your or others [colleagues/stakeholders] capacity, skills or expertise?
- Has the i-Tree Eco project led to you/others to being able to secure funding to expand the urban tree resource?

4. Enduring connectivity:

- Has the i-Tree Eco work led to any new collaboration within your or with other organisations?
- As a result of i-Tree Eco have you or anyone within your organisation changed your attitudes to engaging/working with researchers?

5. Culture/attitudes towards knowledge exchange:

- Who do you think are the key audiences for i-Tree Eco results and reports?
- If you know or found out about an i-Tree Eco report how did that happen?
- Have you seen a full i-Tree Eco report?
- Have you seen a short summary i-Tree Eco report?
- Do you think the i-Tree Eco outputs (e.g. full report, summary) produced need any translation to make them easier for you to understand?

6. Challenges and barriers:

- Are you aware of any barriers/challenges that have reduced the impact of i-Tree Eco?
- What could be done in the future to avoid some of the problems or issues outlined above?
- The values for urban trees not currently captured by i-Tree Eco. Can you let us know whether these values of urban trees are also important in your opinion?

Appendix 3. Interview questions

- What is your role in the organisation?
- When did you get involved in, or become aware of, the i-Tree Eco survey work?
- How did you get involved, and why?
- What do you know about how the i-Tree survey and reporting was run?

1. Conceptual:

- What level of interest has there been in the i-Tree work/reports?
- Has this interest been in the key headline results or in the detail of the survey, or anything else?
- Has the i-Tree Eco work changed your understanding of, or attitude towards, urban trees and their value, and the benefits they provide to society?
- And do you think the i-Tree eco survey work has changed understanding of, or attitude towards, urban trees within your organisation?
- And do you think the i-Tree eco survey work has changed understanding of, and attitude towards, urban trees among others outside of your organisation?

2. Instrumental:

- Has undertaking the i-Tree Eco work and the production of the i-Tree Eco reports resulted in any changes to policy
- or practice that you are aware of?

3. Capacity-building:

- Has involvement in the i-Tree Eco work increased your or others' skills or expertise?
- If yes, what has this led to?
- Has the i-Tree Eco work led to you, your colleagues or others being able to secure funding for urban tree management or expansion?

4. Enduring connectivity:

- Has the project led to any new collaboration within your organisation?

- What was the connection between your organisation and the i-Tree Eco survey team? (Those carrying out the work – only relevant if this was not you and your organisation). Have there been any benefits or challenges for your organisation related to this?
- As a result of the work, have you or any of your colleagues changed your attitudes to engaging/working with others? (External organisations)

5. Culture/attitudes towards knowledge exchange:*

- Who was the audience for the i-Tree Eco survey report? Who should know about the results?
- How were the i-Tree Eco survey results/report made known?

6. Challenges and barriers:

- Are you aware of any barriers or issues that may have reduced the impact of the work?
- What could have been done differently to avoid the issues just described (if anything)?
- Which findings of the i-Tree Eco work do you think are most important, and why?
- Are there any values not captured by the i-Tree work that are relevant for valuing the urban tree resource?
- Is there any other information not captured that you think would have been useful?
- Are there any future plans to do more with this work and its data/results? Any follow on?

*During the study, it became clear that the original questions for 'culture/attitudes towards knowledge exchange' did not capture the precise meaning of this impact type as defined in the literature (Edwards et al. (2017); Meagher et al., 2008; Edwards & Meagher, 2019). Despite this, good evidence for this impact type was obtained from respondents' answers to other questions. In retrospect, an additional question might have been added to the list: 'Have you (or any other stakeholder) changed your attitudes towards knowledge exchange?'

Appendix 4. Summary of impacts identified through the documentary review or reported in the interviews and questionnaire for each project

Case study	Instrumental	Conceptual	Capacity-building	Enduring connectivity	Culture/attitudes towards knowledge exchange
Torbay	Informed a new local tree strategy Data used in Ash Dieback Action Plan for Devon and in Living Ash project Helped secure promotion of tree manager to a more senior, strategic role Helped secure investment in urban forests for 2 years Helped lead to funding for Torbay tree trail Referenced in a government statement on trees, a government woodland strategy, and in the UK NEA	Raised awareness of the importance of urban trees Increased understanding of link between trees and physical activity to health benefits	Improved policy-makers (FC) ability to brief higher level officials	Improved collaboration between policy-makers (FC) and researchers, leading to further research projects Collaboration with NHS on Tree trail	Highlighted importance of working with stakeholders to define project aims
Edinburgh	Fed into and drove new city tree policy/strategy Informed decisions on planning for development of updated Open Space Strategy Helped to maintain budget for tree team at time of cuts Findings used to encourage investment in charitable tree planting scheme	Increased understanding of canopy cover Raised awareness of the tree team	Helped support external tree planting initiative	Improved connections between tree and climate teams	Changed attitude towards the process and the limitations of data gathering and presenting them for impact. Results shared with local community tree groups
Sidmouth	Will inform new district tree strategy and neighbourhood plan Fed into review of the council's tree service Informed Ash Resilience forum Helped secure funding for additional arboricultural officer role Findings used for "master-planning or the management of the urban forest"	Increased understanding of tree species diversity and threats to trees as well as social benefits of trees	The "facts" made community group more confident to make the case for trees	Improved connection with public	Engaged with public throughout survey, including holding event days with speakers and engaging with schools
Bridgend	Informed internal Chalara report Fed into Landscape Design package and work on Sustainable Urban Drainage Systems (SUDS) Made the case for another tree officer	Increased understanding and awareness of tree species and tree health		Improved connections between a broad range of teams (engineers on SUDS, green infrastructure and transport)	Collaborative project teams, consisting of users and researchers
Tawe Catchment	Informed Green Infrastructure Strategy and Wellbeing Assessment Used as evidence in Public Service Boards Informed where new trees should be	Increased understanding of tree species cover and the importance of healthy urban trees	Evidence improved case for management changes	Working with planners and developers on Green Infrastructure Strategy for Swansea	Recognition of the importance of research summaries

	planted Informs new developments guiding species selection		
Glasgow	Informed local climate change reports	Improved understanding of importance of urban trees	Strengthened connections between policy-makers and researchers
	Informed master-planning and the management of the urban forest	Improved understanding of threats to urban trees	

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