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Expectations of i-Tree Eco as a tool for urban tree management in Nordic cities

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While urban forests are recognized as imperative toward climate adaptation in cities and provide health and recreational benefits to citizens, municipal tree officers often struggle to find successful governance arrangements and budget support toward long-lasting investment and implementation in new planting schemes and protection of existing trees. Since its release in 2006, i-Tree Eco has helped urban tree officers worldwide to find tangible leverage in the means of quantitative mapping, numeric measures, and economic values of ecosystem services. This may in turn help ease gridlocks and potentially support constructive dialogues across sectors, with decision-makers and public engagement. With the release of i-Tree Eco v. 6 in Europe 2018, 13 Nordic cities were engaged in a larger research project with ambitions to use i-Tree Eco for the purpose of retrieving numeric and monetary data of the biophysical structures and ecosystem services of the urban forest. Based on questionnaires and semi-structured interviews, we present the results from the Nordic i-Tree project with a focus on expectations, opportunities, and potential barriers experienced in using i-Tree Eco in urban forest management. The most prominent expectation and foreseeing opportunities were recognized toward using numeric information on trees to change policies and support cross-sectoral collaboration while reaching politicians and the public. Identified barriers involved how limited resources are spent on public outreach and how information about the project to relevant stakeholders were not distributed from the beginning which may have implications on the dissemination of results. As some important ecosystem services, e.g., cultural services, are not captured by i-Tree Eco, presenting the partial value of urban trees may pose also potential risks to cross-sectoral collaboration. Other findings conclude that although numeric information on ecosystem services is seen as beneficial in terms of communicating with different stakeholders, a deeper understanding toward the criteria used in the valuation process and the potential risks of numeric approaches may provide more context-specific applications.

KEYWORDS

i-Tree Eco, urban trees, urban forest, ecosystem services, green space management, governance, landscape, green infrastructure

1 Introduction

With increasing urbanization, habitat fragmentation and the forecast of climate change green infrastructure is well recognized at global policy levels for providing a wide range of ecosystem services to benefit urban communities (European Commission, 2019). The urban forest (a collective term for all trees and woody vegetation growing in urban landscapes) plays a pivotal role in the green infrastructural network and as such is paramount to ecosystem services and in preserving natural capital (Zölch et al., 2017). Coined at the beginning of this century, the term ecosystem services embraces the benefits delivered by natural environments to societal welfare and includes clean air, flood protection, pollination, food production, and recreational and aesthetic values. The output of ecosystem services relies on the functioning of the ecosystem, i.e., the capacity of the system to provide services that in turn build upon the biophysical qualities and structures of the ecosystem, i.e., species diversity, age distribution, and habitat configuration (Haines-Young and Potschin, 2010).

While ecosystem functioning and services of urban trees provide a fundament to urban sustainability and can be linked to the UN Sustainability Development Goal 11, consideration to integrate this knowledge into planning and management is often secondary to traditional planning of buildings and grey infrastructures of transport and underground pipe systems (Hagemann et al., 2020; Hamel et al., 2021). Further challenges include low budget support of green space management where urban tree care predominantly occupies risk assessments at operational levels (i.e., maintenance work to reduce risk to buildings and the public) rather than continuing strategies and long-term planning in support of ecosystem services and subsequent benefits (Randrup and Persson, 2009; Davies et al., 2017; Östberg et al., 2018). Integrating the necessity of ecosystem services and the role of urban forests into political discourses and local governance is thus recognized as prioritizing steps toward, e.g., climate adaptation and lasting support of urban landscapes as viable ecosystems (UNECE, 2020). For many urban tree officers and green space managers, tangible leverage in the means of quantitative mapping, numeric measures, and economic values of ecosystem services are seen as pragmatic solutions for future policy making, investments, and cross-sectoral collaboration (Song et al., 2018; Wirtz et al., 2021).

1.1 Ecosystem services, values, and benefits

The concept of ecosystem services (ES) helps explain how human wellbeing is contingent and interdependent on nature and has been classified into four categories of *provisioning* (e.g., food, timber, fuel, and medicine), *regulating* (e.g., climate regulation, erosion and flood control, carbon sequestration), *cultural* (e.g., health, tourism, aesthetical, and recreational values), and *supportive* services (e.g., biodiversity, photosynthesis, and soil formation), where the latter make up the foundational processes toward the necessary functions of the three former services (MEA, 2005).

In the late 20th century, the concept of ecosystem services was closely intertwined with biodiversity conservation but has since evolved into a multifaceted phenomenon from which science and policy making intently elaborate (Czúcz et al., 2020). Hence, the concept is scrutinized both as a complex abstraction and a practice-orientated logic with means to support domains in both academia and the real world (Jax et al., 2018). With the release of the "Millennium Ecosystem Assessment" in 2005, "changes in policies, institutions, and practices" were targeted as the fundamental domains to instrumentally support the protection of biodiversity and reverse the degradation of ecosystems (MEA, 2005, p. 92). This is still of prevailing concern and recognized through, e.g., "The United Nations Decade on Ecosystem Restoration" (2021–2030) on a global level, where initiatives including new political incentives and stakeholder involvement are embedded as necessary steps on local levels (UNEP/FAO, 2020). Where traditional ecosystem conservation in the 20th century diverged from economic growth and development, the concept of ecosystem services has helped stress the interdependency between ecosystem conservation and long-term economic sustainability (Goméz-Baggethun and Ruiz-Pérez, 2011).

How ecosystem services and benefits rely on well-functioning ecosystems are, in its simple form, explained by the cascade model developed by Haines-Young and Potschin (2010) and helps identify the relationship between expected ecosystem services, benefits, and values to the functional characteristics of biophysical qualities and ecosystem functions (Figure 1). The cascade serves as a conceptual approach and can be modified to fit different purposes from explaining complex arrangements for spatial data analysis to organizational and governance situations (Potschin-Young et al., 2018). With the inclusion of potential feedback loops, i.e., how ecosystem services may result in either support or pressure on biophysical structures, process, and function, the cascade model provides a decision-making framework to, e.g., policy making (Maes et al., 2012), green infrastructure planning (Andersson-Sköld et al., 2018), or forest management (Hansen and Malmaeus, 2016).

Whereas objectives are to influence or support alternative decisions at policy, tactical, or operational levels, different values and valuations can be ascribed to different ecosystem services depending on various viewpoints of human relations to non-human nature (Jax et al., 2013), potential conflicts in describing values of incommensurable context and relations (Gómez-Baggethun et al., 2016), and/or finding appropriate valuation units to be incorporated into policy, planning, and decision-making contexts (Barton et al., 2018). With a focus on bridging ecosystem services and biodiversity into economic decision-making (e.g., Costanza et al., 1997; TEEB, 2010; SEEA, 2012), concerns have been raised with regard to, e.g., the commodification of ecosystem services and of ecosystem services developing into a transitory short term tool (Goméz-Baggethun and Ruiz-Peréz, 2011). The operational challenges of coordinating ecosystem services into, e.g., policy making has been exemplified based on potential uncertainty among decision-makers toward the reliability and accuracy of ecosystem service appraisals (Barton et al., 2018).

The information gap hypothesis was developed as part of the EU "OpenNESS" project to aid ecosystem service appraisals for governance support and decision-making (Barton et al., 2018). It follows a modified version of the cascade model (Potschin-Young et al., 2018) to capture potential information gaps and to better understand when, how, and why uncertainties arise toward ecosystem

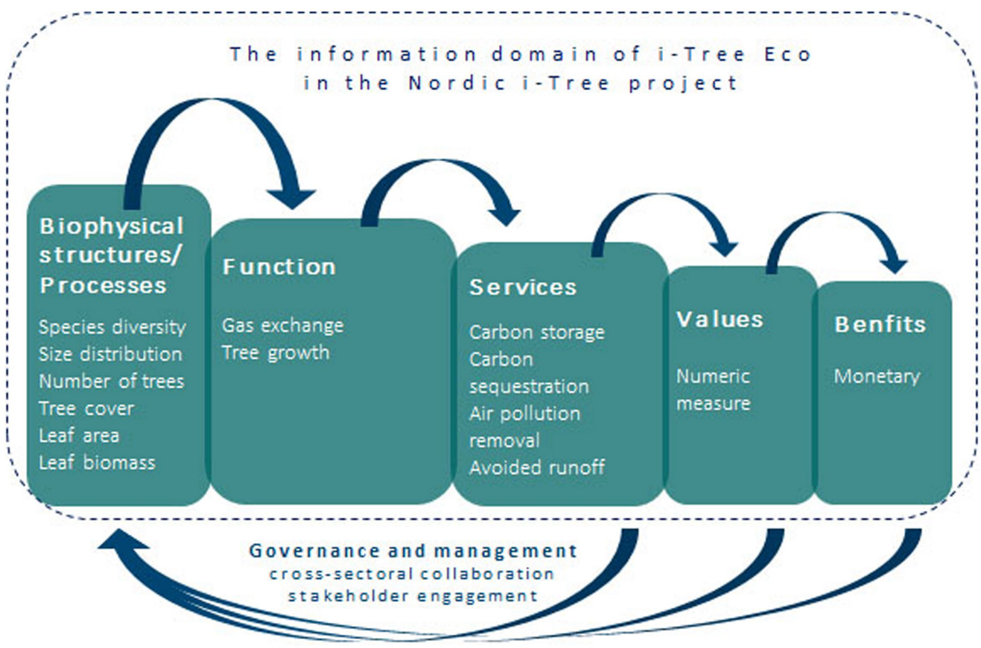

FIGURE 1
Cascade model developed by Haines-Young and Potschin (2010) explained in the context of i-Tree Eco. The data from i-Tree Eco provide information on the biophysical structure of the urban tree population, followed by ecosystem function, services, values, and benefits.

appraisals. Incorporated in 26 case studies and 80 ecosystem services appraisals, the hypothesis included four identified themes or purposes that usually guides the intention of applying the ecosystem service concept:

1) *informative* (to change perspectives of public and stakeholders).
2) *decisive* (to help distinguish between alternative decisions).
3) *design* (to calibrate the scope and targeting of policy instruments and management actions), and.
4) *explorative* (knowledge testing in relation to research).

It was summarized that if the approach is systematically applied to capture uncertainties in, e.g., policy-making processes, and to encourage knowledge co-production with stakeholders, operational gaps will be limited to ecosystem services appraisals.

1.2 The i-Tree software

Developed by the USDA Forest Service, the i-Tree tool box helps provide measurable information on trees and is recognized to quantitatively assess biophysical structures, regulating ecosystem services and subsequent benefits provided by the urban forest (i-Tree, 2019). It comprises several web-based tools, e.g., i-Tree Design for support in decision-making regarding design and energy savings with a focus on the spatial relationship between individual trees, smaller tree populations, and adjacent buildings; i-Tree Canopy which relies on Google maps for overall estimations on tree canopy cover and associated ecosystem services; and i-Tree Database allowing international users to submit local data (e.g., tree species information, and precipitation and pollution data) to be processed into the i-Tree Eco tool (Nowak et al., 2018). Initiated in 2006, i-Tree Eco is described as the "flag ship tool" of the i-Tree software suite providing functional analysis of ecosystem services, information on biophysical structure and composition, and forecasting modeling options and prognosis for future events, e.g., plausible damage caused by pest outbreaks and future tree populations totals. Since its release, i-Tree Eco is currently adapted for use in Canada, Australia, the United Kingdom, Mexico, Europe, Colombia, South Korea, Japan, and New Zealand and is expected to have more than 320,000 international users in at least 130 countries (Nowak et al., 2018). The strength of the program lies in its continuous development and adaptation to local contexts and conditions around the world (e.g., incorporating local data on climate and pollution), and its requirement of field data collection which in turn contributes to more accurate estimations on, e.g., ecosystem services (Nowak et al., 2018; i-Tree International, 2022).

Today, local authorities commonly use i-Tree Eco in order to reach different stakeholder groups from private organizations and individual citizens to decision-makers and public institutions of, e.g., municipal departments and schools. Often the tool is used to directly involve the urban community in field inventories. Prominent examples are the One Million Tree Projects in the US, canopy assessments and community engagement in Australian cities, and municipal initiatives of valuing natural capital in cities throughout Europe (i-Tree International, 2022). City administrations in a number of European countries have now concluded extensive evaluations and projections of their urban tree stock using i-Tree Eco, e.g., the inner and outer boroughs in the city of London in the United Kingdom in 2015; the evaluation of the urban forest in Strasbourg, France, 2016; and of 14 municipalities in the Netherlands in 2019 (*Ibid.*).

With the input of field data, tree information, climate, and pollution data, the software estimates a range of regulating ecosystem services (e.g., the amount of avoided runoff, air pollution removal, carbon sequestration, and storage), and biophysical information (e.g., species diversity, size classification, leaf area index, and biomass). Numerical information on biophysical qualities also helps assess potential risks concerning future effects of insect and disease outbreak and helps identify the relation between leaf area and leaf biomass to the output of ecosystem services. For ecosystem services, the information is provided in metrical measure (e.g., removal of nitrogen dioxide in kilograms, carbon storage in metric tons, avoided runoff from storm water in cubic metres) and in monetary value (social and utility costs, compensatory value, etc.) (Nowak, 2021). Field measurements and subsequent biophysical valuation provide numerical information of value to operational maintenance and to long-term management prognosis of, e.g., securing species diversity and ecological succession. The numeric information on ecosystem services in turn helps describe how different species and specific trees contribute to a social good, where easily accessible measures may support cross-sectoral communication and public outreach.

1.3 The governance and management of Nordic urban forests

The governance and management of the majority of publicly owned trees reside with local authorities in Sweden, Norway, and Finland, where management decisions usually fall to one division within the organization or are split between several depending on land use context, e.g., the highway authority for street trees and the parks division for trees in parks and recreational settings. However, management responsibilities may also lie with third sectors such as housing companies and cemeteries (Persson et al., 2020). This silo structure of management organizations gives rise to complexity as different land use management and ownership contribute to an *ad-hoc* approach in the management strategy and may obstruct a comprehensive management procedure for the urban tree population as a whole. With an additional 40%–50% of the urban forest populating private land, e.g., residential areas, further complications are identified toward an integrated management approach, e.g., in support of a comprehensive succession and species diversity and/or mitigating climate impacts in targeted areas (moderation of temperatures or rainfall interception, etc.) (Pauleit et al., 2017). Indeed, climate change and its detrimental effects on biodiversity, human health, social welfare, etc., significantly requires cross-sectoral collaboration and co-governance procedures where several mitigation and adaptation strategies can be allocated within the green infrastructure domain. For example, win–win solutions regarding storm water planning or heat regulation call for waste water divisions and public health services to recognize investments in green infrastructure and the urban forest. In turn, tree and park officers seek means to influence policy levels (e.g., political decision-making and financial budget support), tactical levels (e.g., cross-sectoral collaboration and engagement in early planning processes), and operational levels (e.g., maintenance activities, protection of mature trees, and new planting schemes) as described in Jansson et al. (2019), in order to secure a consecutive approach for long term planning and management. This is not only the case for urban tree management in the Nordic countries but can be seen as generic to urban tree stewardship on an international level (Song et al., 2018; Ordóñez et al., 2019; Wirtz et al., 2021).

1.4 The Nordic research collaboration of i-Tree Eco as a tool in urban tree management

Due to the European release of i-Tree Eco in 2018, a joint Nordic research initiative was established in 2017 between the Swedish University of Agricultural Sciences (SLU) in Sweden, Norwegian Institute for Nature Research (NINA) in Norway, and National Resources Institute in Finland to guide and assess the application of i-Tree Eco in 13 cities (Figure 2). The conception of the project was initiated from the strong tree advocacy in several Swedish cities engaged in the Swedish Tree Association, from which a partnership was conceived between SLU and nine larger cities. This was followed by an opportunistic interest from the cities of Turku, Tampere, and Helsinki in Finland, and the city of Oslo, Norway, due to a previous economic evaluation of urban nature (Barton et al., 2015). In general, the case studies were cities with active research teams, good access to data, and policy interest.

Proceeding from 2017 to 2021, the project involved collaborations between researchers and practitioners in workshops, presenting, discussing, and evaluating i-Tree Eco as a tool for assessing urban tree ecosystem services. In common, the participating cities recognized the i-Tree Eco tool for communicating the values of urban trees, and field inventories were carried out in line with current strategic plans for each city. In Sweden, all cities conducted plot inventories within the city district administrative border including both public and private land. In Norway, information from airborne laser scanning was used in tandem with a set of auxiliary spatial datasets to capture the municipal tree population of Oslo, including public and private trees. In Finland, complete inventories were conducted in three cities with a focus on trees in city areas subjected to infill development or maintenance activities.

The aim of this study was to investigate the attitudes among urban tree officers toward the potential use of i-Tree Eco v.6 as a tool for urban tree management in the 13 Nordic cities. The study focuses on how participating tree officers viewed and sought to apply the tool, and the study will not elaborate on the "black box" of the software which is described in Nowak (2021). The objective of our project extends from the study by Raum et al. (2019) by which i-Tree projects in the United Kingdom were evaluated with regard to achieved impacts. However, rather than evaluating the impact on management, we focus on identify (1) early motives and expectations using numeric and monetary values of ecosystem services, (2) challenges and opportunities when incorporating i-Tree Eco as a tool in municipal tree management, and (3) provide a critical reflection to future guidance and assessment during the initial phase of using i-Tree Eco in municipal tree management.

2 Materials and methods

The study comprised a mixed methods approach including an initial questionnaire arranged in a Likert scale mode followed by semi-structured interviews. The questionnaires were distributed to all tree officers participating in the i-Tree projects (Table 1) using the conceptual framework developed by Nutley et al. (2007) and described in Meagher et al. (2008) and Raum et al. (2019). The framework was initially designed to assess the impact of social science research on non-academic policy and practice where knowledge transfer was

FIGURE 2
Geographical location of participating cities in the Nordic i-Tree Eco project, 2017–2021.

investigated from the definitions of *instrumental use or impact* and *conceptual use or impact* (Meagher et al., 2008), followed by *capacity building*, *connectivity*, and *culture and attitude toward knowledge exchange* (Raum et al., 2019). We applied the framework in order to identify early challenges and motives in using i-Tree Eco and how this was recognized as an impact potential to policy and decision-making. We also applied the framework to determine if and how collaboration with the scientific community was considered useful to practitioners working with urban tree management, using the i-Tree Eco tool to support decision-making.

A total of 16 questionnaires were distributed by email to participating tree officers, and 12 semi-structured interviews were conducted using the video conference solutions of Zoom and Teams. The conceptual framework for the questionnaire and the semi-structured interviews included the following themes:

1) *Instrumental impact* refers to potential impact on plans, actions, decisions, and policies and was categorized into sub-themes of (i) management and (ii) funding.
2) *Conceptual impact* relates to potential changes to knowledge, awareness, and attitudes and included the sub-themes of (i) biophysical information and ecosystem services, (ii) numerical information, and (iii) monetary information.
3) *Capacity building* helps frame the ability to excel expertise.
4) *Connectivity* refers to future relationships and trust in i-Tree data.

TABLE 1 Number and affiliation of participating managers with responsibilities of the city trees in the Nordic i-Tree Eco projects.

City	Country	Local authority affiliation		
Malmö	Sweden	Landscape architect		
Helsingborg	Sweden	Landscape architect		
Hässleholm	Sweden	Tree and park officer		
Kristianstad	Sweden	Tree and park officer		
Gothenburg	Sweden	Tree and park officer		
Borås	Sweden	City gardener		
Stockholm	Sweden	Tree officer		
Umeå	Sweden	Tree and park officer		
Luleå	Sweden	Tree and park officer		
Oslo	Norway	Urban Forester		
Oslo	Norway	Park manager		
Tampere	Finland	Environmental designer		
Tampere	Finland	Tree officer		
Turku	Finland	Tree officer		
Helsinki	Finland	Design specialist		
Age	30–40	40–50	50–60	60–70
n=	7	4	3	2
Years in sector	>10	10–20	30–40	
n=	8	2	6	
Gender	Female	Male		
n=	6	10		

Of all 16 participating managers, 10 were male and 6 female subjects, with the vast majority in the age group of 30–40 yrs. ($n = 7$), followed by the age group 40–50 yrs. ($n = 4$), 50–60 yrs. ($n = 3$), and 60–70 yrs. ($n = 2$). Working experience in the municipal tree sector varied from ≈10 yrs. ($n = 8$), to 10–20 yrs. ($n = 2$), 30–40 yrs. ($n = 6$).

5) *Culture and attitude toward knowledge exchange* helps delineate the role of research and that of the researcher in collaborative projects between academia and practice.

The arrangement of the questionnaire is presented in Table 2.

The semi-structured interviews followed the same thematic framework of concepts as described for the questionnaire and aimed for a qualitative approach with open-ended questions in order to expand on underlying reasons and experience (Appendix 1). Although the interviews were structured from a thematic research framework, the interviews followed a phenomenological approach, i.e., the respondents were given time to elaborate on experiences and answers based on their natural professional attitudes in a lifeworld known to them (Bevan, 2014; Husserl, 2017). Each interview lasted for approximately an hour and was conducted from February to June 2021.

2.1 Analysis and collocations of questionnaires and semi-structured interviews

The answers from the questionnaire were arranged in a Likert scale mode and subsequently analyzed in order to retrieve mean values and standard deviations (SD) (Appendix 2).

The semi-structured interviews were fully transcribed and analyzed using inductive coding to identify themes and conceptual patterns from the data set. The interview material was then allocated to an Excel spreadsheet to allow for both qualitative and quantitative assessment of identified themes. From a discussion point of view, we elaborated on the four typologies from the information gap hypothesis on ES appraisal from Barton et al. (2018), including *explorative*, *decisive*, *design*, and *informative* purposes into the initial themes of *instrumental impact*, *conceptual impact*, *capacity building*, *connectivity*, and *culture and attitude toward knowledge exchange*.

3 Results

The overall results from the questionnaire and semi-structured interviews indicate how the foremost concerns and expectations of using i-Tree Eco are for informative and design purposes on policy and tactical management levels (Table 3). This is particularly true with regard to the themes of *instrumental impacts in management and for funding*, *capacity building*, and *connectivity*. In regard to *conceptual impacts of biophysical information and ecosystem services*, the three primary concerns are of design purposes on tactical levels whereas *conceptual impact with regard to numeric and monetary value* can be linked to decisive purposes for both policy and tactical levels. The final theme of *culture and attitude toward knowledge exchange* shows how collaboration with research is regarded for explorative and decisive purposes to be integrated on tactical management levels. The following sections provide a detailed description of the results for each theme, starting with the primary concerns and ending with the least important assumptions. In the semi-structured interviews, it was evident that age, gender, and years of working in the sector had limited impact on how i-Tree was thought to be elaborated into the organization's daily work or the tree officers' expectations from the tool (Table 1).

3.1 Instrumental impacts—management

According to the questionnaire results, 94% ($n = 15$) of the respondents strongly agreed and 6% ($n = 1$) agreed that raising awareness of urban trees as natural capital through monetary valuation was the most important instrumental impact on management (Figure 3). In comparison to other responses, it had the highest mean value of 4.94 and an SD of 0.24, followed by *expectations to stimulate changes to policy making* and *to gain a better understanding and mapping of ecosystem services* (4.88 mean value, SD 0.33 respectively). This corresponds to the qualitative answers from the semi-structured interviews where "reaching politicians and decision-makers with tangible facts and numbers" was a principal motivation for using i-Tree Eco ($n = 8$). One respondent explained that with facts and numbers "*we can better understand trees as assets*" and by doing so "*influencing public opinion [and] regard trees more than nuisance and aesthetic elements*." The advantage of defining ecosystem services through numeric values is interlaced in the interview answers but with a focus on reaching decision-makers rather than increasing in-house expertise. As an instrument for impact on management, i-Tree Eco is consequently recognized as a communication tool where besides politicians and decision-makers cross-sectoral collaboration is also of

TABLE 2 Framework of core questions included in the questionnaire put forward to cities in Sweden, Norway, and Finland.

1 Instrumental impacts: What would the main purpose be for your department to use i-Tree Eco?	
1.1 Management	
A.	To stimulate changes to policy making for urban trees?
B.	To prioritise management of existing trees in areas of spatial development (e.g., high value trees in areas subject to infill development or expansion on the urban fringe)?
C.	To improve the spatial targeting of newly planted trees (e.g., to ecosystem service deficit areas)?
D.	To gain a better understanding of the species diversity and succession of the urban tree population?
E.	To gain a better understanding of potential outbreaks of pests and diseases and which trees are at risk?
F.	To gain a better understanding and mapping of ecosystem services of the urban tree population?
G.	For carbon accounting purposes?
H.	To raise awareness of urban trees as natural capital through monetary valuation?
I.	To support economic compensation claims for damage to municipal trees?
1.2 Funding	
A.	To increase the potential of funding to conduct long term planning of the urban forest?
B.	The potential of funding to conduct future inventories and data collections?
C.	To increase the potential of funding to maintenance work?
D.	To increase the potential funding for tree planting schemes?
E.	To increase the potential funding for maintenance of continuous planting of trees?
F.	To increase the potential funding of new members of staff within our organization?
2 Conceptual impacts	
2.1 How do you relate to the following statement:	
A.	My expectations are high regarding the implementation of i-Tree Eco
2.2 Which findings and claims do you think will be most useful to you and your organization?	
2.2.1 Biophysical information and ecosystem services (not monetary values)	
A.	The structural and biophysical information on the urban forest as a whole (species diversity, age distribution, etc.)
B.	Information and measures of the quantity of carbon sequestration and storage
C.	Information and measures of the quantity of air pollution removal
D.	Information and measures of the quantity of avoided storm water runoff
E.	Information and measures of the quantity of BVOC emissions.
F.	The measure of canopy cover.
2.2.2 Numerical information (not monetary values)	
A.	I trust the algorithms used in i-Tree Eco and that the numerical outputs are reliable, i.e., conforms to the characteristics of the tree population in my city.
B.	The numeric information provided by i-Tree Eco will provide better support to my work compared to suggestions with no reference to quantitative data.
2.2.3 Monetary information	
A.	The monetary value provided by i-Tree Eco will provide better support to my work compared to suggestions with no reference to monetary valuation.
B.	The monetary value regarding air pollution removal is of particular interest.
C.	The monetary value regarding carbon sequestration and storage is of particular interest.
D.	The monetary value regarding avoided storm water runoff is of particular interest.
E.	The monetary value regarding the structural value of the urban forest is of particular interest.
2.3 How do you reflect on the following?	
A.	I find that i-Tree Eco captures all the relevant information and values of the urban tree population that I have use for in my work
3 Capacity building through i-Tree Eco	
3.1 How do you expect the involvement in i-Tree Eco has increased your or others (colleagues / stakeholders) capacity, skills or expertise?	
A.	The involvement in i-Tree Eco has so far led to an increased capacity and expertise for myself and colleagues at my department

(Continued)

TABLE 2 (Continued)

4 Connectivity through i-Tree Eco	
4.1 How do you expect current engagement with i-Tree Eco has influenced interest in the project?	
A.	I recognize an interest and support for my work with i-Tree Eco among colleagues from my department.
B.	I recognize an interest and support for my work with i-Tree Eco from members and colleagues outside my own department – e.g. in other departments and other actors in the municipality.
C.	I deliberately and actively engage in informing my colleagues about my work with i-Tree Eco.
D.	I deliberately and actively engage in informing other departments about my work with i-Tree Eco.
E.	I deliberately and actively engage in informing citizens/members of the public about my work with i-Tree Eco.
5 Culture and attitude toward knowledge exchange	
5.1 Which experiences so far do you recognize from your work with i-Tree Eco?	
A.	I find the i-Tree Eco software user friendly.
B.	I find that the collaboration with SLU / NINA / LUKE is beneficial to our application of the i-Tree Eco tool.
C.	I find that I have received sufficient support and information from the project coordinator at SLU / NINA / LUKE.

The questions were answered in a five-level Likert scale, ranking from strongly disagree to disagree, neutral, and agree to strongly agree. Each thematic section included an open question for respondents to add qualitative comments.

interest. It was clear from the semi-structured interviews that reaching out to neighboring divisions (e.g., water and sewage departments) and to urban planners (in order to integrate existing and new tree planting in strategic spatial plans) counts toward this motivation ($n = 7$). This is in line with the interest expressed by interviewees ($n = 8$) in protecting existing trees, as i-Tree Eco is considered a tool that can help highlight the value of mature trees.

Using i-Tree Eco in support of *mapping potential outbreaks of pests and disease* ranked the lowest interest in the questionnaire with 25% ($n = 4$) neutral, 56% ($n = 9$) agreed, and 19% ($n = 3$) strongly agreed (3.94 mean value, SD 0.66). This was followed by *economic compensation claims for damage to municipal trees* (4.19 mean value, SD 1.07) and *understanding of the species diversity and succession of the urban tree population* (4.31 mean value, SD 0.68) (Figure 3).

3.1.1 Instrumental impacts—funding

Applying i-Tree Eco with the *potential to increase funding for long-term planning of the urban forest* resulted in 75% ($n = 12$) in strong agreement and 25% ($n = 4$) in agreement. In comparison to the other replies in the questionnaire, it presented the highest mean value of 4.75 mean value with an SD of 0.43 and related to the response in the interviews where securing future budgets for protecting existing trees and integrating existing and new tree planting in strategic spatial plans were of concern. This was also echoed in the questionnaire where the *increase the potential funding for tree planting schemes* with 75% ($n = 12$) strongly agreed, 19% ($n = 3$) agreed, and 6% ($n = 1$) neutral, followed by an *increase in the potential funding for maintenance of continuous planting*, where 56% ($n = 9$) strongly agreed, 38% ($n = 6$) agreed, and 6% ($n = 1$) neutral.

Results from the semi-structured interviews revealed contrasting views on the instrumental impact of funding where one respondent explains how "*[the significance of] monetary value has decreased…. I do not believe that the monetary value is enough to justify the importance of urban trees, I do not get money for difficult nature values*," while another respondent explained that "*monetary value is the only vocabulary politicians will understand*."

To increase the *potential funding of new members of staff within the organization* was of minimum concern according to the questionnaire, with a mean value of 3.31 but indicating an SD of 1.4, i.e., 25% ($n = 4$) of the respondents strongly agreed to this potential (Figure 4).

3.2 Conceptual impacts

All of the respondents have *high expectations of the i-Tree Eco tool in support of their study*, i.e., that i-Tree Eco will support changes to knowledge, awareness, and attitudes, where 56% ($n = 9$) strongly agreed and 44% ($n = 7$) agreed. From the semi-structured interviews, expectations were expressed toward changing the awareness of politicians and decision-makers ($n = 5$), changing knowledge within the department ($n = 4$), increasing awareness toward cross-sectoral collaboration ($n = 4$), supporting changes to policy making ($n = 2$), and increase of budget support ($n = 2$). Two respondents addressed the conceptual impact on tree preservation with one tree officer explaining: "*Prior to the i-Tree project I would easily fell disputed trees and compensate for removed trees, I would not do that as readily today.*"

3.2.1 Conceptual impacts—biophysical information and ecosystem services

With regard to biophysical information and ecosystem services, the *measure of canopy cover* was considered of highest interest, 69% ($n = 11$) in strong agreement and 31% ($n = 5$) agreed. In comparison to the other replies, this concluded the highest mean value of 4.69 and SD 0.46. Next, followed *the quantity of avoided storm water runoff*, *air pollution removal*, and *carbon sequestration and storage*, all with 44% ($n = 7$) strongly agreed, 56% ($n = 9$) agreed with equal mean values of 4.44 and SDs of 0.50 (Figure 5). The *structural and biophysical information on the urban forest as a whole, including species diversity and age distribution* is regarded second to last in the questionnaire but specifically brought forward as important data in the semi-structured interviews ($n = 6$). Species diversity is mentioned in relation to increasing the resilience against pests and disease but also to the potential to advocate for non-native species that can manage periods of drought due to climate change. In the interviews, conceptual impact with regard to canopy, cover is raised by two respondents only, whereas the link between knowing the tree location

TABLE 3 Comprehensive results from the questionnaires with regard to expectations and early motives of using i-Tree Eco in urban tree management in Nordic cities.

	Instrumental impact: management	Instrumental impact: funding	Conceptual impact: biophysical information and ES	Conceptual impact: numeric and monetary value	Capacity building	Connectivity	Culture and attitude toward knowledge exchange
	Potential impact on plans, actions, decisions, policies	*Potential impact on plans, actions, decisions, policies*	*Potential changes to knowledge, awareness, attitudes*	*Potential changes to knowledge, awareness, attitudes*	*The ability to excel expertise*	*Future relationships and trust*	*The role of research science and that of the researcher in collaborative projects*
1	Awareness of trees as natural capital through monetary valuation	Potential to increase funding for long term planning of the urban forest	The measure of canopy cover *Species diversity*	The numeric and monetary information provided by i-Tree Eco will provide better support compared to suggestions with no reference to quantitative data	Expected increase in capacity and expertise for the respondent and colleagues	Recognition of interest and support for the work with i-Tree Eco from members and colleagues outside own department	The research collaboration with participating academic institutions was appreciated in the application of i-Tree Eco
Purpose	Informative	Informative	Design	Informative decisive	Informative	Informative	Explorative
Strategic management level	Policy	Policy	Tactical	Policy Tactical	Tactical	Tactical	Tactical
2	Stimulate changes to policy making	To protect existing trees and to integrate existing and new tree planting schemes	The quantity of avoided storm water runoff, air pollution removal, and carbon sequestration and storage	The monetary value regarding carbon sequestration and storage	n/a	Recognition of interest and support for the work with i-Tree Eco from members and colleagues within own department	To integrate research into the application of i-Tree Eco provides credibility and supports transparency
Purpose	Design	Design	Design	Decisive		Informative	Decisive
Strategic management level	Policy	Policy Tactical	Policy Tactical	Policy Tactical		Tactical	Tactical
3	To gain a better understanding and mapping of ecosystem services	To increase the potential funding for maintenance of continuous planting	The structural and biophysical information on the urban forest as a whole, including species diversity and age distribution *The measure of canopy cover*	The monetary value regarding the structural value of the urban forest	n/a	To deliberately and actively engage in informing own department about the work with i-Tree Eco	n/a
Purpose	Design	Design	Design	Informative Decisive		Informative	
Strategic management level	Tactical	Operational	Tactical	Tactical		Tactical	

If the answers differentiate in position between the questionnaire and the semi-structured interviews, the response from the interviews are included in the italic format following the response from the questionnaire. The theoretical framework indicates the themes of (1) *instrumental impact*, (2) *conceptual impact*, (3) *capacity building*, (4) *connectivity*, and (5) *culture and attitude toward knowledge exchange* developed by Meagher et al. (2008) and Raum et al. (2019). The following answers are ranked in order of the three highest expectations for each thematic category with "1" indicating the foremost and highest of expectations, followed by the second inferior expectation indicating "2", etc. The four typologies from the information gap hypothesis on ES appraisal from Barton et al. (2018) further categorize the answers into *informative purposes* (expectations to change perspectives of public and stakeholders), *decisive purposes* (to help distinguish between alternative decisions), *design purposes* (to calibrate the scope and targeting of policy instruments and management actions), and *explorative purposes* (knowledge testing in relation to research). The final category shows which level of strategic management relates to each expectation and means of influence, i.e., policy level (e.g., political decision-making and financial budget support), tactical level (e.g., cross-sectoral collaboration and engagement in early planning processes), and operational level (e.g., maintenance activities, protection of mature trees, and new planting schemes) described in Jansson et al. (2019).

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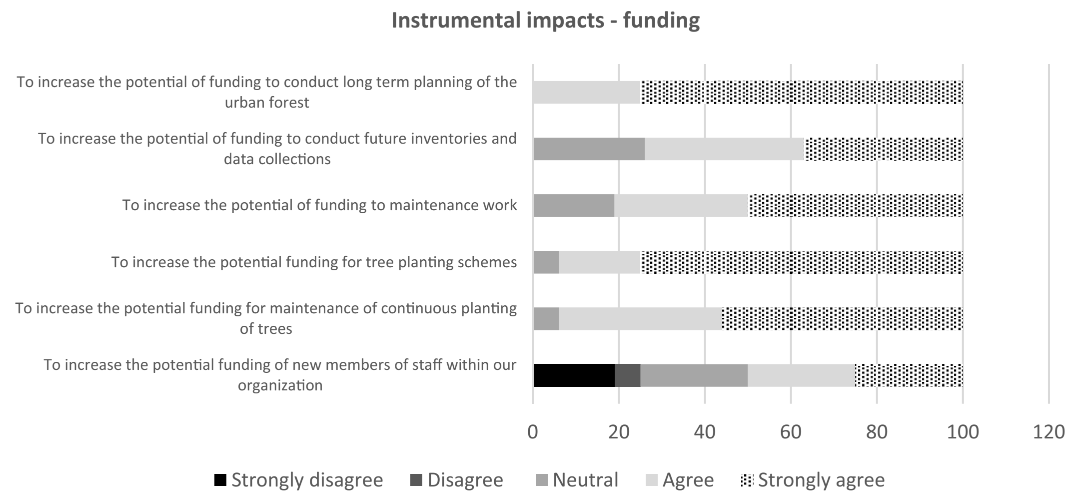

FIGURE 3
Expectations of instrumental impacts with regard to applying i-Tree Eco for the management of urban trees ($n = 16$).

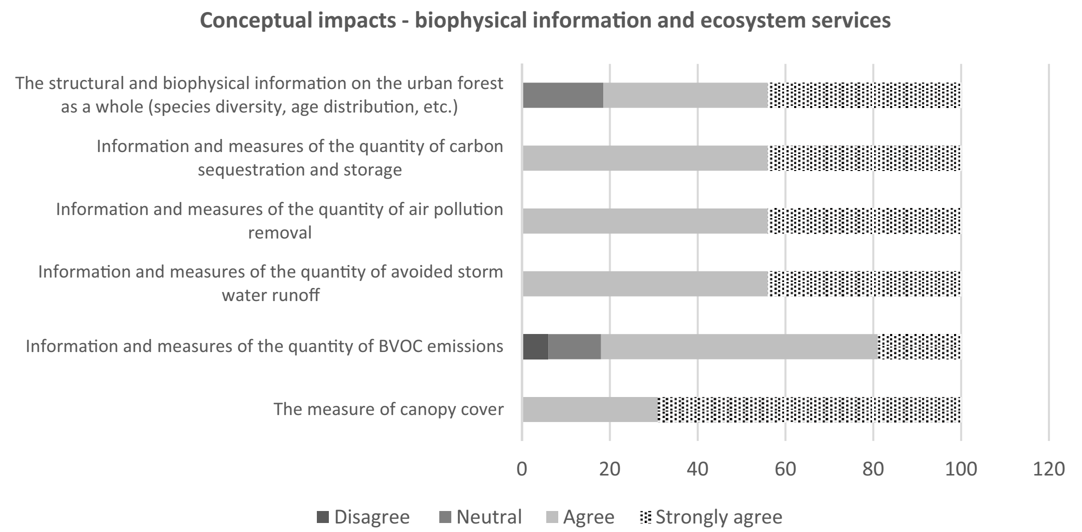

FIGURE 4
Expectations of instrumental impacts with regard to applying i-Tree Eco for potential funding of urban trees ($n = 16$).

in relation to place specific values are brought forward by three tree officers.

3.2.2 Conceptual impacts—numerical and monetary information

The statement of how *numeric information provided by i-Tree Eco will provide better support to the respondents' work compared to suggestions with no reference to quantitative data* received the highest expectation of 69% ($n = 11$) strongly agreed, 19% ($n = 3$) agreed, and 12% ($n = 2$) neutral. A similar response was shared regarding the claim that *monetary values provided by i-Tree Eco will provide better support to the respondents' work compared to suggestions with no reference to monetary valuation*.

Following expectations were, in a consecutive order, the conceptual approach of *monetary value regarding avoided storm water runoff* had 56% ($n = 9$) strongly agreed, 44% ($n = 7$) agreed, and carbon sequestration and storage had 63% ($n = 10$), 31% ($n = 5$), and 6% ($n = 1$). Air pollution removal gained the least interest of all categories (Figure 6).

The consensus from the semi-structured interviews was that numerical and monetary information provides tangible facts that are easy for politicians and the public to understand and that numerical data can be interchangeable in the context of other sectoral departments, e.g., for the division for sewage and water. With reference to numeric data, ecosystem services "*become tangible and comparable to ongoing work at other departments and can better support budget discussions.*" One other explanation was how i-Tree Eco helped explain "*what it would cost [to social good] without the trees.*"

Concerns were also raised with regard to monetary valuations. One respondent pinpointed how monetizing could be a "*double edged sword, especially if the value is too low.*" This was echoed by

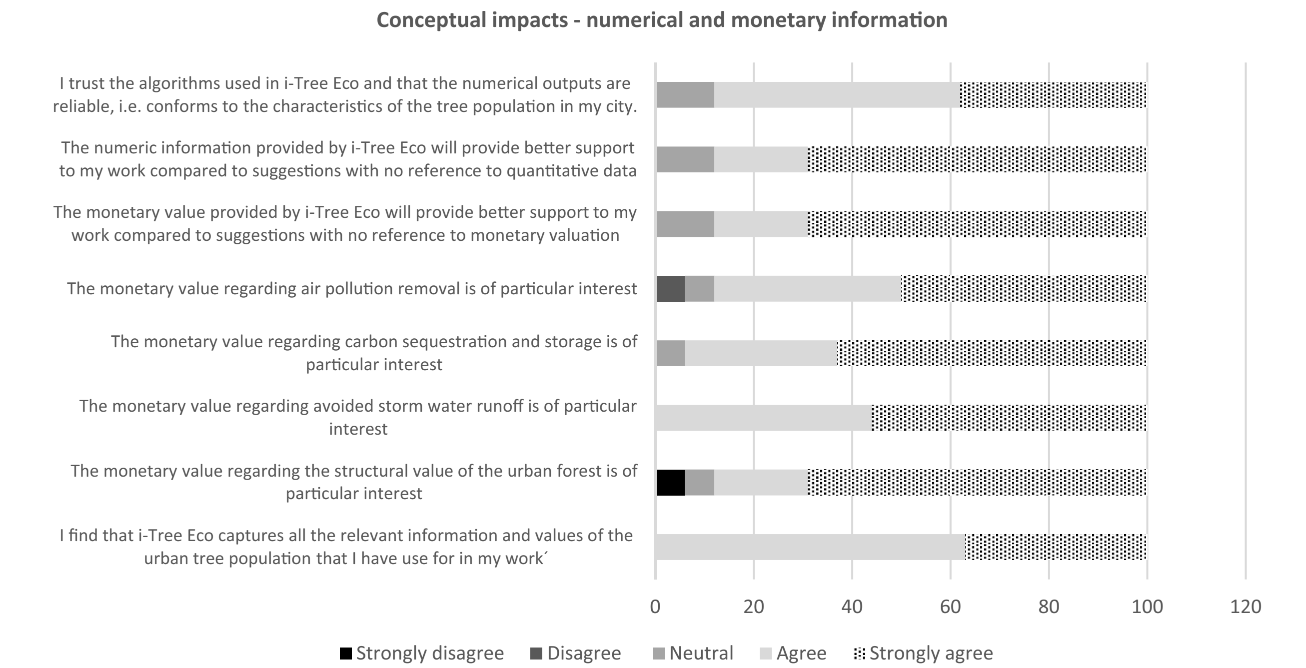

FIGURE 5
Considerations of conceptual impacts of biophysical information and ecosystem services from using i-Tree Eco ($n = 16$).

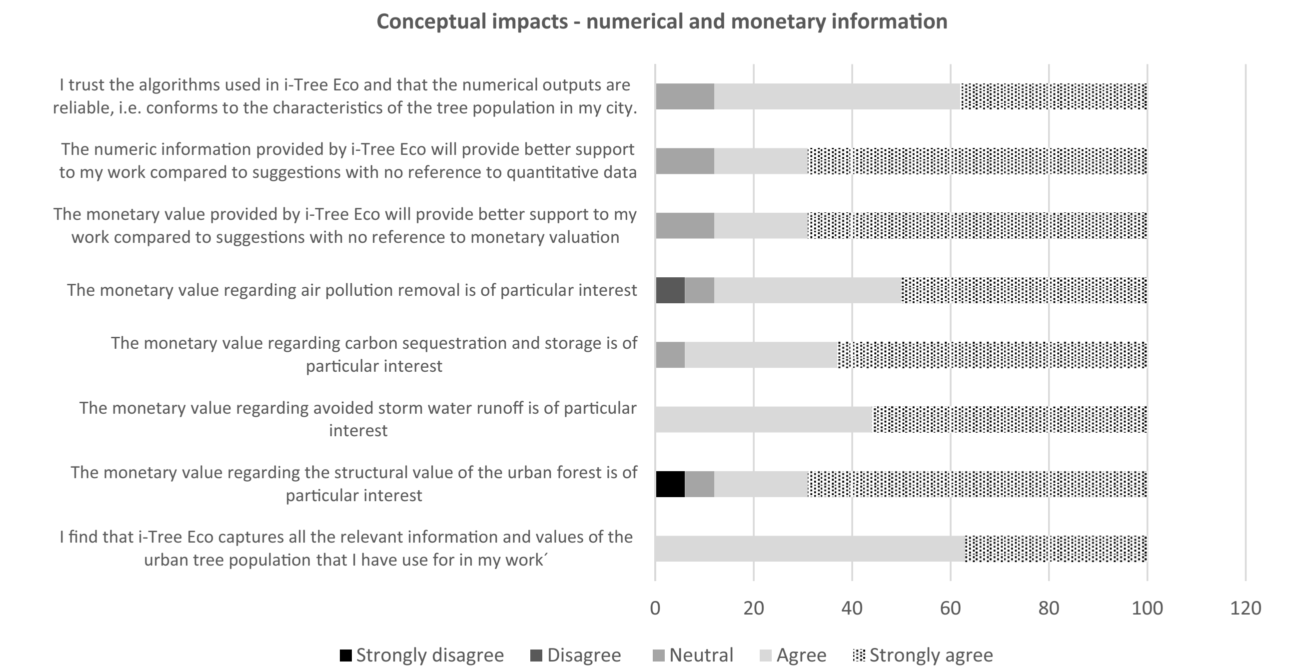

FIGURE 6
Considerations of conceptual impacts of numerical and monetary information from using i-Tree Eco ($n = 16$).

other respondents with examples of potential risks to cross-sectoral collaboration if monetary benefits of ecosystem services would prove limited. Other ecosystem services not captured by i-Tree Eco, e.g., cultural services, were also of strong interest to some respondents ($n = 6$) but with recognition to its limitation to quantify benefits.

3.3 Capacity building

Concerning whether the involvement with i-Tree Eco had so far *led to an increased capacity and expertise for the respondent and colleagues* 6% ($n = 1$) strongly agreed, 75% ($n = 12$) agreed, and 19% ($n = 3$) were neutral. From the semi-structured interviews, all respondents except one recognized their own role and responsibility toward capacity building, and it was clear that at least eight cities had actively engaged in presenting the work with i-Tree Eco within their own departmental forums and in cross-sectoral seminars. Community outreach was also acknowledged as part of capacity building with one respondent explaining how "*[I] need to be better in finding creative ways to reach private homeowners. The most important groups are those who decide on issues and public opinion, influencing them is the most important*." One tree officer claimed how the work with i-Tree Eco had helped an understanding toward tree preservation rather than tree felling which was echoed by another respondent arguing that "*My work is tied to the money in use, and citizen feedback, most of which concern that trees should be cut down.*"

3.4 Connectivity

Response toward the suggestion that respondents *recognize an interest and support for the work with i-Tree Eco from members and colleagues outside their own department* received the highest support of all queries with 25% ($n = 4$) strongly agreed, 56% ($n = 9$) agreed, 12% ($n = 2$) neutral, and 6% ($n = 1$) disagreed. This differentiated from the other replies with a mean value of 4.0 and a SD of 0.79. The respondents found *an interest and support for the work with i-Tree Eco among colleagues at their department* with 25% ($n = 4$) strongly agreed, 50% ($n = 8$) agreed, 19% ($n = 3$) neutral, and 6% ($n = 1$) strongly disagreed. With regard to their own engagement if they *deliberately and actively engage in informing their own department about the work with i-Tree Eco* 12% ($n = 2$) strongly agreed, 38% ($n = 6$) agreed and were neutral, respectively, and 6% ($n = 1$) disagreed and strongly disagreed, respectively (Figure 7).

Community outreach, as *engagement in informing citizens and members of the public about the work with i-Tree Eco*, had the least support with 12% ($n = 2$) strongly disagreeing, 69% ($n = 11$) neutral, and 19% ($n = 3$) in agreement. From the semi-structured interviews, 40% ($n = 6$) explained that lack of connectivity on all levels was due to the early phase of using i-Tree Eco and that future connectivity and trust would improve in time. Several interviewees ($n = 5$) stressed the importance of communication for enduring connectivity, and two respondents explained the exercise of broadcasting media in support of connectivity.

3.5 Culture and attitude toward knowledge exchange

The role of *research collaboration with participating academic institutions was appreciated in the application of i-Tree Eco* resulted in 57% ($n = 9$) in strong agreement toward its benefits, and 31% ($n = 5$) agreed, 6% ($n = 1$) was neutral, and 6% ($n = 1$) disagreed. Regarding the integration of research into the application of i-Tree Eco, 50% of the respondents in the semi-structured interviews mentioned its benefit in providing credibility and supporting transparency. One tree officer argued that working in close contact with researchers and academia "*[…] help connect it [the work with i-Tree Eco] to a wider forum of national interest.*"

With regard to finding the software of i-Tree Eco user friendly, the majority were neutral by 57% ($n = 9$), 25% ($n = 4$) agreed, 12% disagreed, and 6% ($n = 1$) strongly disagreed. From the interviews, it became evident that many respondents found the visual graphics confusing and "outdated" but appreciated the program for being free to download. However, during the interviews, some respondents ($n = 6$) stated that they had not personally used the i-Tree Eco tool and instead had delegated the inventory and input data process to an assistant.

The final question asked in the semi-structured interviews was regarding the main audience that received the results from the work with i-Tree Eco. While politicians and decision-makers, in-house colleagues, and cross-sectoral colleagues were all recognized equally important, reaching the urban public received most responses. Only 16% ($n = 2$) included private landowners as an important target group.

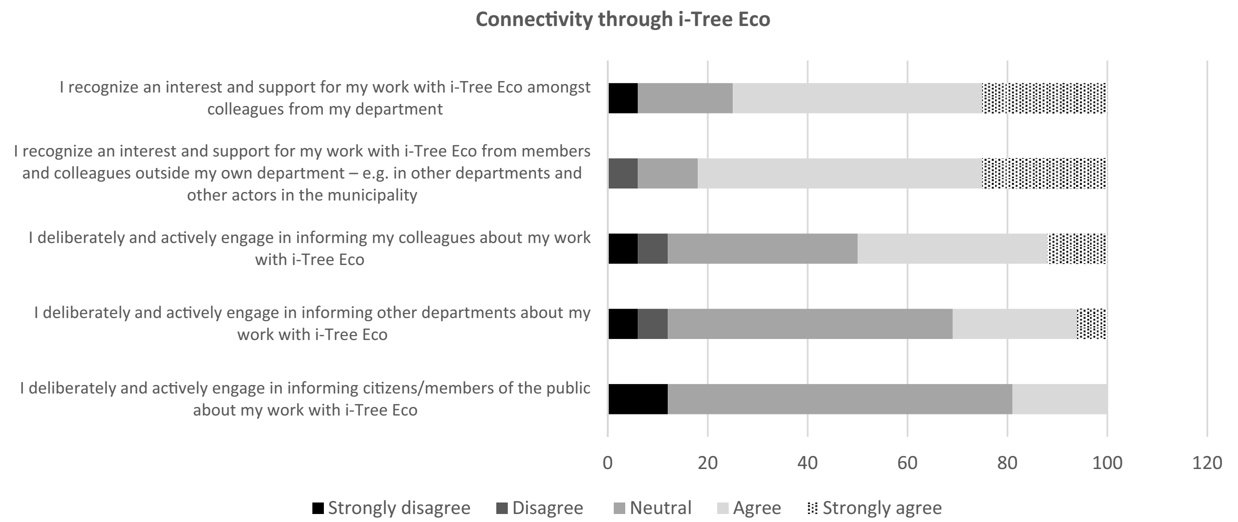

FIGURE 7
Results from the questionnaire regarding views on how i-Tree Eco may support connectivity ($n = 16$).

4 Discussion

The results from the questionnaire and semi-structured interviews demonstrate how the purposes of retrieving information from i-Tree Eco is considered to strengthening the management of the urban forest as biophysical structures and also indicates how some of the information can support a better understanding of how services, values, and benefits can be elaborated and used in decision-making and cross-sectoral collaboration.

Whether instrumental impact precedes conceptual impact or vice versa (i.e., how knowledge is needed prior to instrumental change or not) is discussed in Raum et al. (2019) with regard to i-Tree Eco and the protection and management of urban forests in the United Kingdom. It echoes the idea that the understanding of numeric data and numbers cannot be independent of related rationality (Foucault, 1972), which in turn explains why some of the answers from the questionnaire in our study seemed to overlap with regard to expected instrumental and conceptual impacts. For instance, the major response for expected instrumental impact relating to management was *raising awareness of urban trees as natural capital through monetary valuation* which directly correlates to conceptual impacts on numbers and monetary values as to change awareness and attitudes. During the semi-structured interviews, it became clear that the respondents perceived the two themes as distinct trajectories as they had the opportunity to critically reflect on their natural attitudes within their professional lifeworld over time (Bevan, 2014). Similar response can also be found in the study by Beery et al. (2016) in which municipality officials and politicians in Sweden were interviewed concerning perceptions of the ecosystem services concept and results showed how conceptual application was often discussed tandem to instrumental use.

4.1 Expectations and opportunities

Clear expectations exist of how *instrumental impacts* of i-Tree Eco may influence policy levels with both informative and design intentions, i.e., to raise the awareness of trees as natural capital with an outreach to politicians and the public with subsequent effects on budgets. This in turn would result in more resources toward new planting schemes and protection of existing trees. Tangible numbers and facts are seen as an advantageous approach to reach relevant stakeholders, including politicians (Qiao et al., 2018; Ordóñez et al., 2019), and the monetary benefits of ecosystem services are recognized as the main leverage in this discourse and correlates to the aspiration to stimulate changes to policy making for urban trees. This corresponds to the findings described in Raum et al. (2019), where insufficient policy drivers were recognized as one major motivation for using i-Tree Eco.

While limited research exists in the field of how i-Tree Eco may influence policy levels or not, several success stories tell of cities influencing policy and decision-making mechanisms by addressing trees as a vital capital, e.g., climate adaptation and public health. Examples include the many "one million trees" projects around the world that also help create environmental awareness among urban citizens. Individual examples that can be linked to i-Tree as a tool to influence policy levels are, e.g., the action plan for future planting priorities in the City of Edinburgh, United Kingdom, environmental strategies to increase canopy cover and new woodlands in London, United Kingdom (Hand and Doick, 2018; Greater London Authority, 2023), and means to advance concrete tree management policies in 14 municipalities throughout the Netherlands (i-Tree International, 2022).

How the results from using i-Tree Eco in the Nordic study can be applied for decisive purposes (to help distinguish between alternative decisions on a tactical level) was not so evident from the results of the questionnaire. However, this was highlighted in the semi-structured interviews, where 60% of the respondents stressed the ambition for cross-sectoral collaboration and the possibilities for decisive impacts on spatial planning. Using i-Tree Eco for the potential of funding for long-term planning and continuous tree planting schemes thus link the instrumental impacts on policy levels to tactical level ambitions, where cross-sectoral collaboration plays a crucial role (Jansson et al., 2019). In Finland, tree officers hoped that i-Tree would help their communication with city planners. To the Swedish tree officers, the "division of sewage and water" was recognized as the foremost potential partner in cross-sectoral collaboration. Several respondents stressed current collaboration as challenging with limited arguments of numeric and technical facts linking trees to avoided runoff. Calculations of i-Tree Eco are thus anticipated to ease current grid locks and potentially support constructive dialogues. This in turn would not only contribute to win–win situations in terms of collaborative decision-making but also to space effective solutions in light of synergetic approaches toward climate adaptation and urban densification (i.e., simultaneous consideration to urban heat and runoff retention in the same place).

With regard to cross-sectoral consultation on strategic spatial planning and design, the results from Oslo in Norway, and Helsinki, Turku, and Tampere in Finland can be used for such decisive and design purposes since preceding field measurements were based on complete inventories linked to spatial contexts, e.g., existing infrastructures, surrounding buildings, and land use. For the cities in Sweden, the results compromise this approach due to the aggregate nature of plot inventories set in relation to lack of land use categorization within Swedish cities and municipalities and rather fits informative purposes on a policy level (Cimburova and Barton, 2020).

The semi-structured interviews also revealed that some Swedish cities continued to use i-Tree Eco as an instrumental tool even after the Nordic i-Tree project was completed. In particular, smaller cities with less complex logistics between and within divisions showed innovative approaches in how to use i-Tree Eco for specific aims. How the size of an organizational unit affects, e.g., collaboration, communication, and knowledge flow (Serenko et al., 2007) and how managers help foster trust and cooperative relationships (May and Winter, 2007) may well influence potentials of how i-Tree Eco and similar tools can effectively be employed, e.g., long term instrumental impacts. The organizational environment including factors such as size, logistics, and trust plays a decisive role in *capacity building* and *enduring connectivity* and to which extent individual tree officers can advocate and pursue their stewardship. Nevertheless, i-Tree Eco may well be an appreciated catalyst in finding new routes toward future tree management and is described by one tree officer: *"Through [i-Tree] Eco, you get basic quality information, it increases your desire to see if you can retrieve more information about other things, [it] increases your interest, expands your way of thinking."*

4.2 Identified challenges

Limited response is given from respondents to *instrumental impacts* on the operational level, e.g., funding of maintenance work. This correlates to a survey conducted in all Nordic Cities by Randrup and Persson (2009), showing how the majority of resources and budget support (up to 80%) are allocated to maintenance and other operational activities. Using i-Tree Eco with the aim of further secure funding for maintenance is therefore considered a surplus. While the majority of the total budget is allocated to maintenance activities, limited support has been found toward long-term planning and management (Randrup et al., 2017; Fongar et al., 2019; Randrup et al., 2021). However, a long-term planning and management approach is both interconnected and contingent with activities on the operational level, e.g., related to performing tree inventories and optimizing ecosystem services via irrigation and pruning (Dempsey and Burton, 2012). For instance, a limited understanding toward the biophysical structure of the urban tree population will compromise investments toward ecosystem services (Gómez-Baggethun and Barton, 2013) and increase potential threats of tree decline based on potential outbreaks of pests and diseases (Sjöman et al., 2014).

The questionnaire results suggest that, in terms of conceptual impacts related to biophysical information, understanding the extent of canopy cover is considered more crucial than knowing the species diversity and age distribution of trees. However, this consequently mismatches the results from the semi-structured interviews where species diversity is brought forward by six respondents as key to biophysical information. One explanation could be of overlapping the understanding of instrumental conceptual impact when answering the questionnaire and that conceptual impacts of biophysical information become clearer during the interviews. Indeed, the canopy cover is stressed by two respondents only during the semi-structured interviews and its numeric approach is questioned by one tree officer: "*The measure of canopy cover is a blunt approach and easily understood, but what is rather required is to understand what parameters are included in, let us say, 25%? Perhaps it should be 30% or it is enough with 15%—why do we set these targets?*" The response illustrates a critical viewpoint on what appears to be an ongoing trend toward universal standardization, aiming for an ideal amount of tree canopy cover in cities (Ordóñez et al., 2019; Konijnendijk, 2022). Careful assessments of a city's current canopy cover and other biophysical structures, such as habitat types, spatial orientation of surrounding buildings and roads, and private and public space, are necessary to establish an initial baseline. Without this baseline, using the quick canopy measure provided by i-Tree Eco (and i-Tree Canopy) could create a spatial distance between management practice and the actual biophysical qualities of urban forests. This issue has been described in the context of carbon metrics by Moreno et al. (2016). In practical terms, measure of canopy cover should link to place-specific qualities, as raised in the interviews, in order to estimate the amount of trees in relation, e.g., to public accessibility (Zhou and Kim, 2013), health (Raum et al., 2019; Kondo et al., 2020), environmental justice (Schwarz et al., 2015), and ecosystem disservices (von Döhren and Haase, 2015; Teixeira et al., 2019).

Although the *conceptual impact of numeric information and monetary benefits* are recognized as the main leverage toward changing policy making, the numeric and monetary approaches are also complex and may backfire on initial intents (Ernstson and Sörlin, 2013; Breed, 2022). This can be exemplified if the resulting beneficiary value is too low compared to the running costs of existing traditional grey infrastructures or if the numeric value of the trees is transferred toward investments in traditional solutions, i.e., the numeric information on ecosystem services from trees can be assigned and replaced by green roofs, underground infiltration tanks, etc.

One explanation toward the scarce interest in using i-Tree as an inventory tool and for economic compensation is that most cities already have a comprehensive database of the municipal tree stock and use existing methods for economic compensation claims including the International Society of Arboriculture's Guide for Plant Appraisal (ISA, 2020), the Danish VAT03 compensation value model (Randrup, 2005), and the LITA Model (Östberg and Sjögren, 2016). Similar to Raum et al. (2019), a number of participating cities also found that manual field measures and data collections were resource intensive and involve extensive undertakings and that the application of i-Tree Eco would benefit if pre-existing data, e.g., from airborne laser scanning, could be brought into the i-Tree Eco program (Cimburova and Barton, 2020).

While consideration toward public outreach is deemed important and the urban public is the most critical target group (in *culture and attitude toward knowledge exchange*), limited resources are allocated toward public engagement in the municipalities. This is reflected in the modest response in the questionnaire to which extent participating tree officers actively engage in informing citizens and members of the public about the work with i-Tree Eco. The lack of interacting engagement between tree officers and the public may relate to the traditional conception of a state-centered management of public space which in turn embeds an undisputed trust that the municipality will make accurate decisions and delivery of services grounded on public taxes (Randrup et al., 2017). However, engaging the public and local communities toward democratic use and access to urban trees and green space is recognized as an indispensable approach for long-term development of urban forests (Sheppard et al., 2017; Ordóñez et al., 2019) and to integrate ecosystem services and natural capital into mainstream economic policy (Costanza et al., 2017). A strategic approach where a proportion of the tree management budget is distributed toward public participation may be a solution in the cause of addressing this concern and to allocate further resources.

Recognized barriers toward *knowledge exchange* and *capacity building* are the underlying abstract mechanisms behind i-Tree calculations and finding the i-Tree v.6 interface complicated to use. According to some tree officers, the first point in question may affect the level of confidence in situations with, e.g., decision-makers when explanations are needed toward *how* the values of, e.g., ecosystem services have been retrieved. It provides a gap between *explorative* (understanding of ecosystem values) and *design purposes* (changes to policy).

4.3 Reflections from the i-Tree Nordic project regarding initial steps of i-Tree Eco application in urban forest management

Measuring services and benefits from the urban forest for the purpose of strategic management requires tree officers, urban foresters, and green space managers to be sure of the motives behind the measure, e.g., for the purpose of strategic management. Furthermore, the contextual complexities from which the measures will be conducted and applied need to be carefully considered too (Barton et al., 2018). With the aim to provide a comparable estimate to already established practices (e.g., traditional storm sewer systems and health and safety costs due to effects from pollution) or to reach decision-makers with convincing information, insights into what exactly is being measured and which comparable indices are justified become essential (Jax et al., 2018). Providing non-academic professionals with accessible information on the underlying mechanisms of numeric valuations would be an important initial step. Today, this information is available via scientific studies on the i-Tree platform but is far from user-friendly. This may prevent practitioners from a critical assessment toward appropriate inventory methods, how to apply valuations to relevant contexts, and confidently explain the results to colleagues and decision-makers.

Although expectations of i-Tree Eco are high regarding changes to knowledge, awareness, and attitude toward the concept of ecosystem services, research shows that further definitions of the different services may be required for successful implementation of conceptual impacts within an organization or to specific tasks (Beery et al., 2016). One of the expectations in the Nordic i-Tree projects was to use the conceptual understanding of ecosystem services with tactical means for cross-sectoral collaboration. Although i-Tree Eco may provide specific and potentially decisive definitions of avoided runoff and carbon sequestration, the question remains if the conceptual use of ecosystem services needs further mainstreaming in order to fundamentally become integral to cross-collaborative planning and management on a daily basis (Potschin-Young et al., 2018). Embedded in this context lies the participation and engagement of the public and local community where science-based information could help stimulate a dynamic and community-centered approach to urban tree management and the urban ecosystem (Costanza et al., 2017). In this perspective, both private and public-owned green space and trees matter, and although private trees were part of the i-Tree valuation in the Swedish cities, limited interaction with private homeowners occurred. Considering that trees on private residential land may compose 40%–50% of the total city tree population (Klobucar et al., 2021), it is evident that future challenges for urban tree management in the Nordic countries include information exchange with private stakeholder groups and inventories of trees on private land use (Östberg et al., 2018).

Most of the respondents in our study argued that steps toward *enduring connectivity* were too early to assess due to the initial phase of just retrieving results from i-Tree Eco. However, research has shown that early engagement in reaching out and informing relevant stakeholders (in-house and third-party colleagues, decision-makers, and the public) supports the foundation toward long-term acceptance and cognitive recognition toward possible outcomes (Head, 2007). We thus recognize a strong potential in future applications of i-Tree Eco to engage and inform different stakeholders as a strategic approach early in the project. This will also help guide future rendering of results, i.e., which format and media will reach relevant groups with what necessary information.

5 Conclusion

While urban forests are recognized as imperative toward climate adaptation in cities and provide health and recreational benefits to citizens, municipal tree officers often struggle to find successful governance arrangements and budget support toward long-lasting investment and implementation in new planting schemes and protection of existing trees. Since its release in 2006, i-Tree Eco has helped urban tree officers worldwide to find tangible leverage in the means of quantitative mapping, numeric measures, and economic values of ecosystem services. This may in turn help ease grid locks and potentially support constructive dialogues across sectors, with decision-makers and public engagement. The most prominent results from our study reveal how expectations from tree officers, urban foresters, and green space managers were foremost directed toward the ability to change policies and support cross-sectorial collaboration by the use of i-Trees' numeric information. In doing so, it was believed that both politicians and the public could be better reached via tangible numbers. However, we identified barriers related to limited resources spent on public outreach. This included a lack of information about the project to relevant stakeholders from the beginning, which is believed to have implications on the dissemination of the final results.

In light of climate change and increasing urbanization, reaching out to other sector groups is imperative as these complex challenges need cross-sectoral collaboration. How trees in the urban landscape can help mitigate and adapt to weather extremes and climate change need to be easily communicated with tangible evidence. The conclusion from our interviews with Nordic tree officers indicates that although numeric information on ecosystem services is seen beneficial in terms of communicating with different stakeholders, a deeper understanding toward the criteria used in the valuation process and the potential risks of numeric approaches may provide more context-specific applications. This understanding will not only support how to reach consensus on policy and tactical levels but also provide guidance on an operative level toward strengthening the biophysical structure of the urban forest and the following ecosystem functions and services as explained by the cascade model.

The concluding take-home messages from the Nordic i-Tree project thus explain how.

1) *instrumental impacts* of i-Tree Eco were foremost recognized to advance cross-sectoral collaboration and to influence policy levels with limited recognition to affect maintenance and operational activities.

2) complete inventories (applied in the cities in Finland and in Norway) should foremost be employed for *decisive* and *design* purposes while plot inventories (applied in the Swedish cities) fit *informative* purposes on a policy level.

3) the organizational environment, e.g., size, logistics, and trust, plays a decisive role to *capacity building* and *enduring connectivity* and to which extent individual tree officers can advocate and pursue their stewardship and.

4) confidence in using the i-Tree Eco tool for *knowledge exchange* and *capacity building* is important in order to understand how and why certain ecosystem values are derived (from the i-Tree program) and how this knowledge in turn can advance capacity building and changes to policy. Providing non-academic professionals with accessible information on the underlying mechanisms of numeric valuations would be an important initial step.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

JDS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Visualization, Writing – original draft. E-MT: Conceptualization, Data curation, Funding acquisition, Investigation, Validation, Writing – review & editing. MM: Data curation, Investigation, Writing – review & editing. ŽC: Conceptualization, Data curation, Investigation, Writing – review & editing. SS: Writing – review & editing. DB: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Writing – review & editing. TR: Methodology, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2023.1325039/full#supplementary-material

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