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Research article

International approaches to protecting and retaining trees on private urban land

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ABSTRACT

Most studies of urban forest management look at vegetation on public land. Yet, to meet ambitious urban forest targets, cities must attempt to maintain or increase trees and canopy cover on private urban land too. In this study, we review and evaluate international approaches to protecting and retaining trees on private urban land. Our study combines a systematic academic literature review, two empirical social science studies on the views of urban forest professionals, and a global case study review of innovative regulations and incentives aimed at protecting and retaining trees on private urban land. Case studies were evaluated for the extent they exceeded minimum standards or went beyond 'business-as-usual'. We found that the most innovative mechanisms combine many regulations, instead of relying on a single regulation, and use financial incentives to retain or plant trees in newly developed or re-developed sites, as well as private residences. We did not find any cases where appropriate monitoring was in place to determine the efficacy and efficiency of these mechanisms. We also found no single simple solution that could effectively and efficiently protect and retain trees on private land. Only by combining policies, planning schemes, local laws, and financial incentives with community engagement and stewardship will cities protect and retain trees on private land. Useful and innovative ways to protecting and retaining trees on private land involves providing solutions at multiple governments levels, embedding trees in existing strategic policy and management solutions, incentivising positive behavior, creating regulations that require payment up front, and engaging the broader community in private tree stewardship.

1. Introduction

This study recognizes that trees on private land provide benefits to the broader public and so it is important to understand how trees on private land can be retained or enhanced. In cities dominated by residential suburbs the majority of urban forest canopy cover is often provided by trees on private land (Troy et al., 2007; Nowak and Greenfield, 2020; FAO, 2018). Many major world cities are undertaking ambitious

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tree planting programs (McPherson et al., 2011; Plant et al., 2017) or setting ambitious canopy cover targets for future decades (Escobedo et al., 2008; TNC, 2019). To meet these increasingly ambitious plans, many local governments are taking a holistic approach to urban forests that spans both public and private ownership (Konijnendijk et al., 2006; Ordóñez and Duinker, 2013).

Influencing what happens to trees on private land is difficult because most urban forest research focuses on public land, so there is little guidance in the literature for those tasked with meeting the challenges. From a local government perspective, some of these difficulties include administrative and legal issues that are not easy to resolve. For example, trees on private land are invisible to the property and titling system, which includes easements and improvements to built structures. Although a tree is regarded as a fixed part of a property and can improve the value of that property, trees change hands outside the jurisdiction of government. This leaves a gap in the data that makes it difficult for local governments to implement proactive tree protection or retention schemes. Secondly, while a tree can be said to be privately owned because it exists on a private property (or more accurately, in the soil of a property), tree crowns and roots can cross boundaries. More generally, some tree benefits, such as temperature regulation or air pollution mitigation are positively externalized, benefiting the public regardless of tree location or ownership (Dobbs et al., 2013; Le Roux et al., 2014; Pearce et al., 2015). Although tree protection can be legislated (Profus and Loeb, 1990; Conway and Urbani, 2007; Hilbert et al., 2019; Lavy and Hagelman, 2019), trees are not always adequately described or accounted for in existing legal, financial, and/or planning systems. This makes it difficult for local governments to achieve urban canopy cover targets at the city-scale because poor protection of trees on private land enables continued tree removal and canopy loss in the private realm (Hurley et al., 2019). At the same time, local governments must communicate and consult with private landowners over the future of trees on their land, but the resources required to do such work are costly (Kirkpatrick et al., 2013). Local governments find it difficult to allocate resources for protecting trees on private land because they prioritize public realm greening, where there is a higher chance of these achieving outcomes and increasing benefits to more people. Also, in some cases, local governments have few legal justifications to tell people what to do with trees on their property, and some incentives could generate inequities by allocating public funds that could benefit private individuals. Nonetheless, in some contexts and circumstances, local governments can bring private landowners to court for not abiding to, for example, tre-guidelines for private property development that include tree retention considerations (VLRC, 2017).

Despite the difficulties outlined above, there are many mechanisms in different combinations from one local government to the next, all aimed at protecting trees on private urban land. These mechanisms can be classified in two ways: 1) regulations, which are specific rules that prevent the removal of trees or require tree replacement and/or planting, and involve penalties for non-compliance; and 2) incentives, characterized by specific programs that encourage the voluntary retention or planting of trees. These mechanisms vary widely across cities and countries, where they are influenced by different legal frameworks, governance structures, cultural norms, and land ownership laws (Coughlin et al., 1988; Profus and Loeb, 1990; Schmied and Pillmann, 2003; Conway and Urbani, 2007; Hill et al., 2010). Adding to the complexity, property rights, planning and regulatory terms change from country-to-country. For example, a term such as private land, or private tree protection, may have multiple meanings, depending upon geographical context (DeRudder, 2006; Taylor et al., 2006). As urban forestry becomes a global discipline and profession, there is a need to synthesize knowledge and practice to give guidance on how to deal with the challenges of protecting and retaining trees on private urban land. City decision-makers would benefit from being able to assess innovative mechanisms from other places that could be applied or adapted to their own circumstances.

This study aims to develop an understanding of how different cities around the world are innovating to protect trees on private urban land. Our focus is on innovative tree protection efforts that include strategic and multi-faceted approaches, combining both regulations and incentives. We bring together systematic academic literature reviews, empirical social science data on the perspectives of urban forest professionals, and a review of innovative case studies, to develop this understanding. The findings and recommendations from this research provides the first global review of innovative mechanisms to retain and maintain urban trees and canopy cover on private urban land.

2. Theoretical framework

2.1. Approaches to protecting and retaining trees on private urban land

Urban trees are typically governed by multiple levels of government (Lawrence et al., 2013). For example, in Australia, various provisions for urban tree protection apply at federal, state, and local government levels, resulting in different approaches across cities. Tree protection and retention on private urban land is largely governed through land use planning provisions and local laws (Bush, 2020), which are defined by state and territory governments (Rowley, 2017). Local governments act as planning authorities, applying these state-defined provisions as well as setting and applying local provisions. In Australia, as in other countries (e.g., Europe, see Schmied and Pillmann, 2003; Lawrence et al., 2013; US, see Coughlin et al., 1988; Watson, 2015; Canada, see Conway and Urbani, 2007), the federal government has a limited role in land use planning provisions, policies, or regulations. For example, federal legislation on endangered species may trigger local regulations aimed at protecting somes species of trees.

Land use planning contributes to tree protection on private urban land through planning scheme mechanisms including land use zones, schedules, and overlays. These mechanisms identify land as requiring specific management of trees to align with strategic objectives such as environmental significance or neighbourhood character. Mechanisms may apply to individual trees, or all trees that meet threshold measures such as height or tree DBH (diameter at breast height; Table 1). Many development actions on private land are allowed ‘as of right’, and do not involve planning assessment. Mechanisms to protect trees on private land only apply when the land use planning assessment is triggered, and these triggers are usually specified in the planning scheme of local governments (Table 1).

In addition to land use planning systems, local governments may establish local laws or ordinances to regulate tree removals that require an application for a tree removal permit. Local laws vary significantly across countries and cities (Profus and Loeb, 1990; Schmied and Pillmann, 2003; Clark et al., 2020). Jurisdictions that use local laws to regulate trees on private urban land include US (Landry and Pu, 2010; Sung, 2012; Watson, 2015), Canada (Conway and Urbani, 2007), most European countries (Profus and Loeb, 1990; Schmied and Pillmann, 2003), Australia (Kelly, 2014), and China (Jim and Liu, 2000; Jim, 2004). Significant tree registries (also called Exceptional, Notable, Landmark, Heritage, or other terms, depending on context; see Ritchie, 2019) are also used by local governments to protect trees of special environmental, ecological, or cultural significance, but depending on context, these may be defined by an overlay or a local law (Table 1).

Land-use planning schemes and local laws controlling tree removal are examples of regulatory policy mechanisms (Maddison and Denniss, 2013). Regulatory mechanisms are specific rules that set the minimum standards to which all actions must meet (Bush and Hes, 2018), to identify required (permitted) actions and responses (eg tree retention, conditions under which tree pruning is allowed), as well as actions that are not permitted (eg tree removal). Regulations are often associated with penalties for non-compliance. Penalties vary, but are usually calculated based on the economic, amenity, or ecological and removal value of the tree (i.e., compensatory value and reinstatement costs; see

Table 1
Framework for characterizing regulatory and incentive mechanisms for tree protection and retention on private urban land as business-as usual (BAU) or innovative (based on data from literature review and social data compiled for this study; see Methods and Results).

Example mechanism	Details	Business-as usual (BAU) approach	Innovative approach
Regulations			
Land use planning scheme	Zoning and overlay mechanisms specified in environmental and planning laws, that apply to a specific area of the city	Zoning or overlay for natural or vegetative features that are not specific to trees; encourages retention of mature or high-quality trees; requires permit approvals for trees that are to be removed or altered (e.g. pruned) as part of new developments	Zoning or overlay as BAU approach that is specific to trees; requires all trees to be retained; requires a specific number of trees to be planted and/or retained as part of new developments
Tree listings	Significant tree registry (as either a planning scheme through zonings or overlays, or local law)	Protection for trees of special aesthetic or cultural value; is not specific to private land; is triggered by the size of the tree (e.g., DBH, height, or canopy cover); specifies fines for removal without permit, calculated via compensatory tree valuation formulas[a]	Protection as BAU approach but that applies specifically to private land; does not discriminate based on tree size or species[b]; and uses compensatory tree valuation formulas[a]
Local laws for tree protection	Local tree protection against removal or alteration	Protection triggering permits removing or altering (e.g., pruning) trees; specifies fines for illegal removals, calculated via compensatory tree valuation formulas[a] based on tree size; and is not specific to private land	Protection as BAU approach that applies specifically to private land; does not discriminate based on tree size or species[b]; requires payment in advance as an investment or bond; and uses compensatory tree valuation formulas[a]
Incentives			
Voluntary standard or certification	Standard or certification schemes that specify tree management recommendations for developments	Incentive that encourages retention or discourages removal of vegetation in a development context; is not specific about trees; and is triggered by vegetation size (e.g., height, DBH) or species (e.g., threatened species)	Incentive as BAU approach that codifies the type of vegetation to be retained or added, with trees having a higher value than other vegetation; and does not discriminate by tree size or species[b]
Voluntary financial incentive	Financial incentive for tree retention in new developments or private residences	Incentive that specifies a financial tax rebate for vegetation retention; is not specific to trees; and may be of a fixed value	Incentive as BAU approach that codifies the vegetation type to be retained or added, with trees having a higher value than other vegetation; does not discriminate by tree size or species[b]; and the rebate or grant is calculated via compensatory tree valuation formulas[a]

[a] Compensatory value formulas are usually specific to the area (see Doick et al., 2018).
[b] See results section, literature review, for comments on this.

Doick et al., 2018; van Oijstaeijen et al., 2020). While regulatory mechanisms are usually used for public trees, many cities also used them for privately owned trees (e.g. private tree protection bylaws, or ordinances; see Conway and Urbani, 2007; Landry and Pu, 2010; Sung, 2012; Hilbert et al., 2019).

The other key mechanism type applied to tree protection and retention is incentives (Maddison and Denniss 2013). Incentives are specific activities that encourage the retention or planting of trees. These mechanisms encourage innovate and beyond business-as-usual or regulated responses (Bush and Hes 2018). For many years, the default incentives of many local governments, to the extent that these were specified in local government documentation, wereere the provision of free tree seedlings for private landowners to plant, or public education campaigns highlighting the importance of urban trees (Ordóñez and Duinker, 2013). Nonetheless, other incentives now include grants, tax rebates, provision of arboricultural advice or free tree-care services, as well as supporting citizen-led activities focused on planting or protecting trees on private land or awarding prizes for volunteer activities (Watson, 2015; Daniel et al., 2016; Mumaw, 2017; Bush and Hes 2018).

2.2. Efficacy and efficiency of regulatory and incentive mechanisms

Regulatory and incentive mechanisms are used to promote tree protection and retention and address the various drivers for tree loss. These causes include urban consolidation and densification, increasing house size and shrinking garden size, risk perceptions and the flowon effect through premiums for house insurance (Boulton et al., 2018; Nowak and Greenfield, 2020). The efficacy of these mechanisms is ultimately reflected in the increase or maintenance of the number of trees and amount of canopy cover on private land. In turn, their efficiency is reflected in the effort exerted to design, implement, and enforce them, which can be measured via local government budgeting and personnel.

Based on local information, some authors have argued that regulatory mechanisms are not effective or efficient. These mechanisms are sometimes not enshrined in property or planning laws, have limited coverage, exempt major land uses (e.g., transport ways, military bases), and exempt small and medium sized trees (Coughlin et al., 1988; Watson, 2015). Also, local governments incur high costs for processing permit applications and arborist reports (Currell, 2012; Hilbert et al., 2019). However, some studies have shown that regulation can influence canopy cover and tree numbers (Landry and Pu, 2010; Sung, 2012). Nonetheless, such evaluations are difficult to make across cities, since local regulations and capacity to implement them vary among cities (Conway and Urbani, 2007; Landry and Pu, 2010; Lavy and Hagelman, 2019). While many authors have called for replacing regulations with incentives due to their low efficacy and efficiency (e.g., Coughlin et al., 1988; Watson, 2015), there is not enough information in the literature to assert this beyond an immediate local context.

The efficacy and efficiency of regulatory and incentive mechanisms are difficult to evaluate at a global scale. Generally, these mechanisms are influenced by a complex combination of policy setting, resourcing for decision-making, monitoring and enforcement, political will, and public attitudes, as well as varying degrees of development pressures. This means that the efficacy of regulations is limited by the capacity and resourcing of the regulatory organisation, both in the decision-making process on issuing permits and in the enforcement process for breaching regulations (Bush, 2020). In addition, political will, or the willingness of elected officials and associated bureaucracies to apply regulations and penalties, is a key factor (Zuniga-Teran et al., 2020). This is in part influenced by their perceptions of the level of public support for regulation and its enforcement (e.g., Conway and Lue, 2018). In short, any existing framework that establishes a procedure to evaluate mechanisms in terms of their efficacy and efficiency may: 1) be proprietary and therefore, not in the public domain; 2) apply to mechanisms that are relatively new and require longer monitoring to determine efficacy (Juhola, 2018); and 3) be context dependent and cannot be used to evaluate efficacy and efficiency in other contexts. There appears to be no global criteria or recipe for evaluating the efficacy and efficiency of regulatory and incentive mechanisms.

2.3. Alternatives for evaluating regulatory and incentive mechanisms

While we lack a global framework to evaluate regulatory and incentive mechanisms, a review of international approaches to protect and retain trees on private urban land can have value if we focus on evaluating innovation rather than efficacy and efficiency. We define innovation in two ways. For regulations to be innovative they must go beyond minimum standards. Similarly, an innovative incentive must encourage best-practice rather than simply rewarding business-as-usual approaches. In this research, we explore different approaches through the academic literature on the topic, empirical data on local governments in Victoria, Australia, and social science data on international perspectives of urban forest professionals. This information provided us with an evaluative framework for subsequently evaluating global case studies in terms of their innovation (Table 1).

3. Methods

Our research process involved several stages and datasets. We started with a systematic review of the academic literature, which informed every subsequent stage of the research. We then developed an empirical understanding of the topic through social science research procedures. We first characterized the types of mechanisms that are used to protect and retain trees in private urban lands by undertaking a study across local governments in Victoria, Australia. This enabled us to provide a global perspective of international urban forest professionals' views on the topic. Using these three empirical datasets (i.e., literature review, types of mechanisms used locally, international perspectives), we developed a framework for characterizing innovative regulatory and incentive mechanisms (Table 1). The final stage of the research was a multi-city case study review of innovative regulatory and incentive mechanisms designedto protect and retain trees on private urban land. These methods allowed us to confidently ground our understanding of the protection and retention of trees on private land on the existing literature, on a range of urban forest professional experiences, and on innovative solutions that are being implemented in cities around the world (Fig. 1). We detail the procedures below. All data sources and some details on procedures of data collection and analyses are included as supplementary material (Supplementary Material 1–4).

3.1. Systematic literature review

Following the systematic review guidelines by Pullin and Stewart (2006) and Moher et al. (2009; PRISMA procedures), we developed a protocol for searching and selecting academic peer-reviewed articles (Table 2). The scope of the search was global but limited to English articles. We systematically searched and selected articles based on the following research questions:

1) What is the loss and gain of trees and/or canopy cover on private land?
2) What are the types of mechanisms that cities use to retain and protect trees on private land?
3) What do stakeholders, including local government officers, private developers, and private landowners, think about trees on their private land?
4) What is the effect of private tree protection and retention mechanisms on maintaining or increasing tree numbers or canopy cover on private land?

The search was limited to peer-reviewed articles in academic journals from 1980 onwards. We developed keywords (Table 2) that reflected inclusion and exclusion criteria (Moher et al., 2009) based on our research questions above. Broader terms (e.g., "vegetation", "greenspace", "green area") were used to expand the search. The databases (SCOPUS and Web of Science) we searched within are interdisciplinary, international databases covering a wide range of indexed journals. To avoid discipline-specific bias and lack of replicability, we did not use discipline-specific databases (e.g., EBSCO) or GoogleScholar (i.e., algorithms change by world region). We added two non-indexed journals, 'Arboriculture and Urban Forestry' and 'Arboricultural Journal', due to their discipline relevance (Table 2). Following PRISMA guidelines, we also extracted articles from the reference lists of all articles found in the searches. The search was finalized on June 30, 2019 (inclusive) according to the selection criteria in Table 2 (see also Fig. 2)

Forty-three (43) relevant studies were identified (Supplementary Material 1) and analysed for qualitative content based on established methods (e.g., Boulton et al., 2018). We followed a combination of descriptive narrative and thematic analysis procedures to synthesize the body of literature (Dixon-Woods et al., 2005). This procedure involved reading the articles in full, extracting information from the articles and classifying this information according to themes relevant to the research questions to enable comparison across the article dataset. This resulted in four research themes:

1) urban tree and canopy cover loss and gain on private land;
2) types of mechanisms to retain and protect trees on private land;
3) opinions about trees on private land; and
4) effect of tree protections on tree numbers or canopy cover.

We developed a second layer of sub-themes based on the specific content of the articles to synthesize their content. Some themes were shared while others were mutually exclusive (see Results).

We recognize that there may be academic articles not included in our review. For instance, those published in languages other than English, and many non-indexed articles may have not been found. Rather than exhaustive, our literature review is, at the very least, representative of the 'state of research' on this topic. Our review has some key strengths. The systematic procedure is based on strict inclusion and exclusion criteria specific to urban trees on private urban lands, and this gives us confidence that what we found was specific and relevant to the topic.

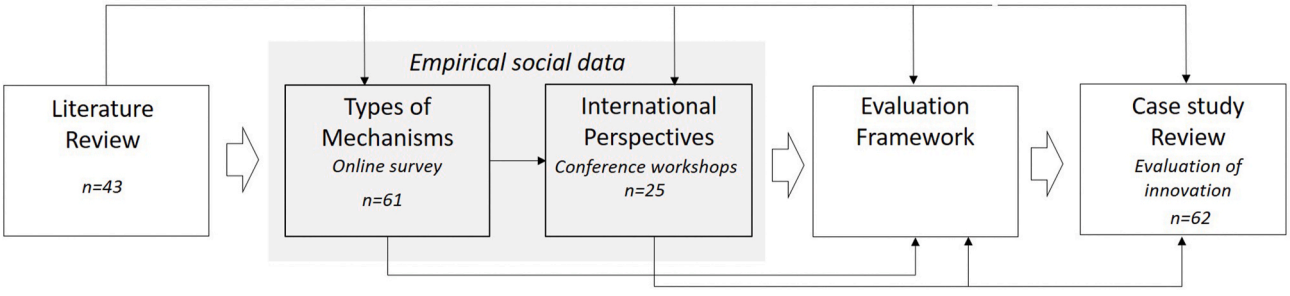

Fig. 1. Stages and procedures of this research and their relationships, indicating number of articles for literature review, respondents or participants for empirical social data, and case study cities for case study review.

Table 2
Literature review stages, including details on procedures and selection criteria.

Stage	Procedure description	Details			
Data Collection	Search for peer-reviewed articles in academic databases and individual journal by title and abstract using keywords, from 1980 to 2019 Databases used: *Scopus* *Web of Science* Non-indexed Individuals Journals used: *Arboriculture and Urban Forestry;* *Arboricultural Journal*	Keywords used[a]: urban city municipal local government city council	canopy cover forest greening green area green infrastructure green space nature natural area street trees tree vegetation woodland	protection retention loss removal	private private land private areas private space private property
Data Screening & Eligibility	Obtain full-text articles and screen and select abstracts from initial searches using selection criteria	*Selection Criteria* 1. Focus on cities or urban areas 2. Focus on trees or urban forests (i.e., tree-dominated systems, including wooded urban area, treed or forested urban area or space) 3. Focus on retention and protection 4. Focus on private land, area, or space			
Data analysis	Classify and consolidate the information contained in the selected articles	Build a database of all studies, consolidate content, develop categories for classification items, use data to create synthesis tables and diagrams			

[a] Bolean operators such as AND OR were used in between groups to include or exclude words in the search.

3.2. Types of mechanisms

We characterized the types of mechanisms that are currently adopted by local governments to protect and retain trees on private urban lands by conducting an exploratory survey of municipal urban forest managers working with local governments in the state of Victoria, Australia. Municipal urban forest managers are defined as the professionals who work within or for local governments (i.e., city councils, municipalities, depending on context) in an urban forest capacity. We aimed to answer the following question:

What are the types of mechanisms used by local governments in Victoria, Australia, to protect and retain trees on private urban land?

Ethics approval for research with human subjects was obtained from [details to be added after review]. Informed consent was obtained from all respondents. No personal information, such as name or affiliation, is explicitly disclosed in this research to ensure confidentiality and anonymity of the participants.

The survey was based on a tailored and exploratory survey design (Dillman et al., 2014). We built on the back of a bigger research study on municipal urban forest manager decision-making in Victorian local governments. The interested reader can read more details about how this survey was designed and delivered in [reference to be added after review]. Respondent recruitment in this study was based on a list of 110 contacts of municipal urban forest managers working in 35 local governments in Victoria, but dominated by 30 of the 32 local governments within Metropolitan Melbourne. We classified local governments following the guidelines of VPA (2018) and an urban-rural gradient lens that helps us understand the unique experience of a city or urban centre (Dobbs et al., 2013). This approach was used to consider context for the types of local governments, but not with the intention of generalizing results for all local governmentss. Also, we did not intend to relate responses to demographic profiles. Rather, we treated the dataset as a collective.

The survey was sent by email to all contacts between April and May 2019. Three reminder emails were sent to increase survey response rates. The survey asked respondents how their local government encouraged the protection and retention of trees on private lands, giving respondents three pre-determined answers based on our theoretical frameworks (Table 1) and space for up to three open-ended answers (Fig. 5; details on survey are included in Supplementary Material 2). The survey also collected some basic employment and demographic data of the respondents. Answers from people not working with local government were filtered out by asking if respondents worked for a local government (yes/no answers; yes answers accepted). We did not ask the names of the local governments where the managers worked to ensure anonymity, given that the contact information of municipal employees is publicly available.

We collected 61 responses (response rate 55.5%) and present results as the frequency with which regulation or incentive themes were selected or mentioned in the survey data (see details in Supplementary Material 2). While not a representative social sample in terms of local government types, the respondents represented a wide variety of local government types (see Supplementary Material 2).

3.3. International perspectives

The goal of this stage of the research was to develop an understanding of tree protection and retention on private urban lands based on the perspectives of international urban forest professionals. These include municipal urban forest managers working directly with local governments, such as arborists, urban foresters, and urban planners, as well as other professionals who work indirectly (contracted) for local governments (see Kirkpatrick et al., 2013; Clark et al., 2020). We aimed to answer the following questions:

1) What are the main concerns about trees on private urban land?
2) Who influences the decisions about trees on private urban land?
3) What is the role of the private land-owning community to protect and retain trees on private urban land?
4) What is the efficacy of mechanisms for protecting and retainin trees on private urban land?

We used a qualitative and exploratory approach to answer these questions (Corbin and Strauss, 2015; Creswell, 2017). We collected empirical social science data by conducting workshops at two international conferences on urban nature (i.e., *The Nature of Cities Summit,* Paris, June 4th, 2019; workshop title: A stick or a carrot? – How can cities retain existing trees and plant more trees on private lands?) and urban forests (i.e., *European Forum on Urban Forestry,* Cologne, May 23rd, 2019; workshop title: How can cities retain existing trees and plant

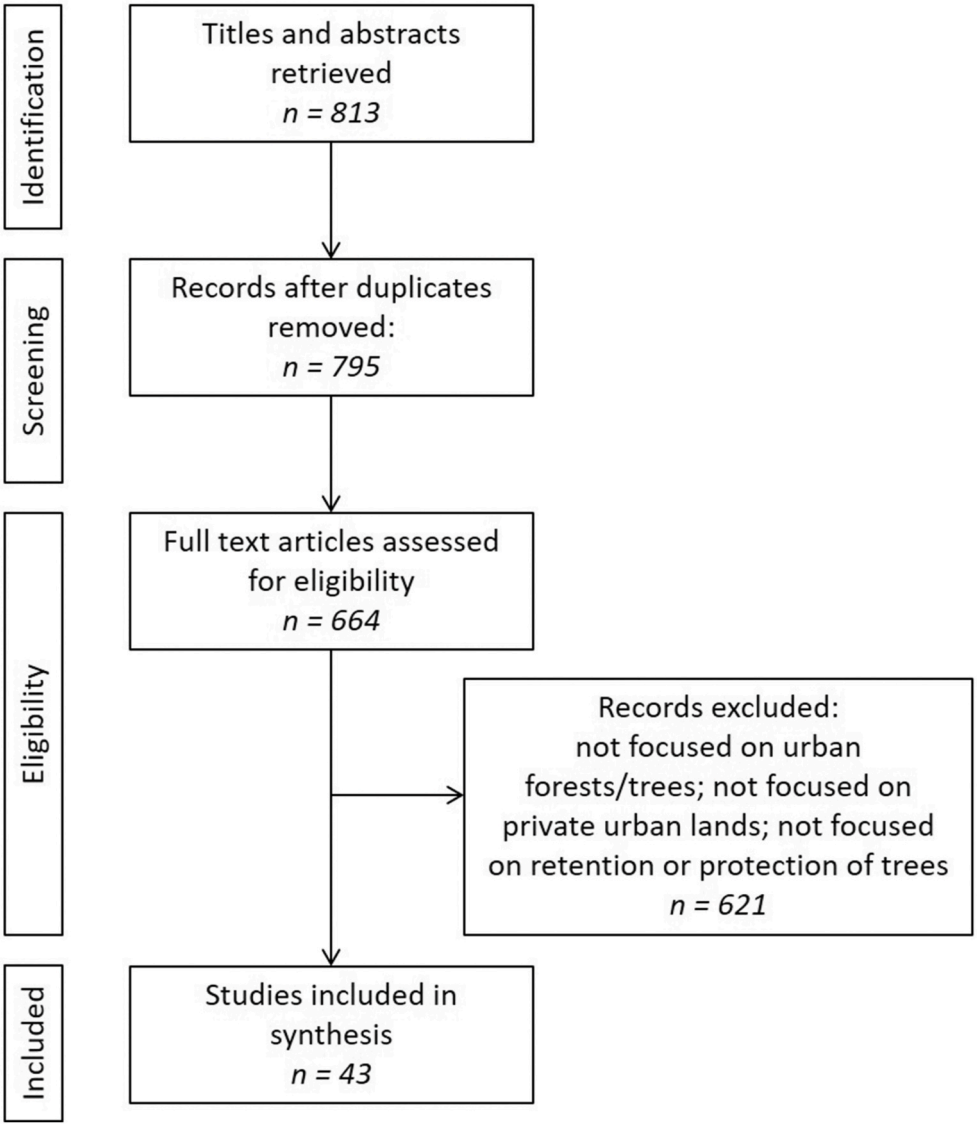

Fig. 2. Flowchart showing the results of the systematic academic literature review.

more trees on private lands?). Time for these workshops was allocated through a conference request for workshop proposals. Ethics approval for research with human subjects was obtained from [details to be added after review]. Informed consent was obtained from all participants. No personal information, such as name or affiliation, is explicitly disclosed in this research to ensure confidentiality and anonymity of the participants.

Participation was based on self-selection. Workshop participants were recruited through the conference programs, as well as by sending email invitations to the list of conference attendees.

The workshops were semi-structured discussions in English stimulated by the two lead authors (and workshop leads) asking a series of research questions (see Supplementary Material 3). These questions were asked in the same way and the same order at each of the two workshops. Workshop conversations were audio recorded, transcribed, and transcripts were imported as data into NVivo 12 Pro (developed by QSR International, 2019). Data were treated collectively, and not by respondent (see demographic profile in Supplementary Material 3). We analysed the data using interpretative, inductive coding techniques (Corbin and Strauss, 2015). Codes were assigned to verbatim responses to convey the ideas being expressed, and these codes were then categorized according to the research questions (examples included in Supplementary Material 3). Coding consistency and accuracy were achieved by applying the principles of densification and constant comparison (Corbin and Strauss, 2015). Densification involves consolidating the number of times an idea is mentioned within the same answer to a question. Constant comparison involves consolidating the number of times an idea is mentioned by examining its representation overall. For example, ideas related to multi-dwelling development projects and private homeowners expanding their built structures as reasons for removing trees on private urban land were coded as the same idea, 'urban densification', given their interrelatedness (Fig. 6). Similarly, ideas related to both budget and personnel as reflective of the role of local government resources were coded as part of the idea of 'resources' (Fig. 6; examples in Supplementary Material 2). All coding was completed by the lead author, who has more than 10 years of qualitative research experience and has conducted previous qualitative studies on municipal manager perspectives on urban forestry.

A total of 25 urban forest professionals participated in the workshops from a wide range of backgrounds. Rather than presenting results in the form of a narrative, the thematic coding approach, allowed us to focus on the frequency, hierarchy, and structure of ideas and relate these ideas to the research questions. These include: 1) the causes of urban tree loss from private urban land; 2) the efficacy of tree protection mechanisms

used by local governments; and 3) opportunities for protecting urban trees on private urban land. This study is not without its limitations. Our insights are restricted to the type of people who attended the workshops. Other people may have wanted to participate in the workshops, but were unable to due to lack of availability. Nonetheless, the strength of this explorative study is that we collected data from people who were interested in the topic and who could provide relevant information about it. Moreover, interpretative coding is essentially reductive, diminishing the nuance of a verbatim answers, and may not be replicable. However, it is an advantegous way to examine social science data by generating data grounded on the view of respondents, focusing on the meaning of ideas rather than the number of times a word is mentioned, and facilitating comparison across verbatim answers. This study provides a good overview of the views international professionals hold about the topic and adds structure to our understanding of how professionals experience how local governments protect and retain trees on private urban lands.

3.4. Case study review

We reviewed global case study cities using innovative regulatory or incentive mechanisms that go beyond minimum standards and business-as-usual to protect and retain trees on private urban land. We were guided by the following research question:

What innovative mechanisms are being used by global cities to protect and retain trees on private urban land?

To preselect the case studies to review, we used the academic literature review and the workshops conducted at the two international conferences to gather potential case studies. We also conducted purposeful and systematic online searches and analysed international databases of urban greening projects (Table 3). In conducting these searches we used the same keywords from our literature review (Table 2), but excluded some more general terms (e.g., "nature", "natural area") to narrow the search. Case studies were selected on the basis of two key exclusion and inclusion criteria:

1) the case study had to be corroborated with publicly available information;
2) the case study had to be innovative, as based on our evaluation framework (Table 1)

Case studies were selected purposefully and not comprehensively. However, the online search for case studies was conducted systematically with the same search procedure applied to all online searches. Given that the number of global cities and diversity of approaches used to manage trees on private land is overwhelming, a comprehensive approach is unwieldy. To make it more manageable, such an approach would have to be restricted to more specific parameters, such as city size, geographical location, or accessibility of information (i.e.,

Table 3
Case study review stages, including details on procedures and selection criteria.

Stage	Procedure description	Details		
Data collection	Case study database search using keywords. Databases used: *ICLEI's C40 program,* https://www.c40.org *100 Resilient Cities,* http://www.100resilientcities.org *Oppla – EU repository of Nature-Based Solutions,* https://oppla.eu *Urban Biodiversity Hub – Case studies map,* http://ubhub.org/map *Naturvation – Urban Nature Atlas,* https://naturvation.eu/atlas *Scopus (academic database)*	*Keywords used:*[a] *Group 1:* private private areas private land private space private property	*Group 2* canopy cover forest forestation greening green area green infrastructure green space street trees tree vegetation woodland	*Group 3* protection retention loss removal
	Search of specific city websites	Purposeful search by city and publicly available information from city websites, following case study suggestions from participants in conference workshops		
Data screening & eligibility	Screen case study summary using selection criteria	*Selection Criteria* 1. Focused on private urban land 2. Included information about tree-dominated systems (including wooded urban area, treed or forested urban area, or single trees) 3. Focused on protection or retention of trees		
	Obtain full-text report, article, or website where information is registered Extract information from document relevant to selection criteria	*Selection Criteria* 4. Information is publicly available via report, article, or website 5. Available in English		
	Select final list of case studies for classification and synthesis using final selection criteria	*Selection Criteria* 6. Information can be corroborated with publicly available documents (e.g., official report, schedule, guideline, consulting reports available in official website, guideline document, presentation, and/or website); 7. Regulations were included if they went beyond minimum standards (Table 1) 8. Incentives were included if they went beyond business-as-usual (Table 1)		
Data analysis & synthesis	Classify and synthesize data	Build database of all case studies, classify content to create synthesis tables and diagrams		

[a] Bolean operators such as AND OR were used in between groups to include or exclude words in the search.

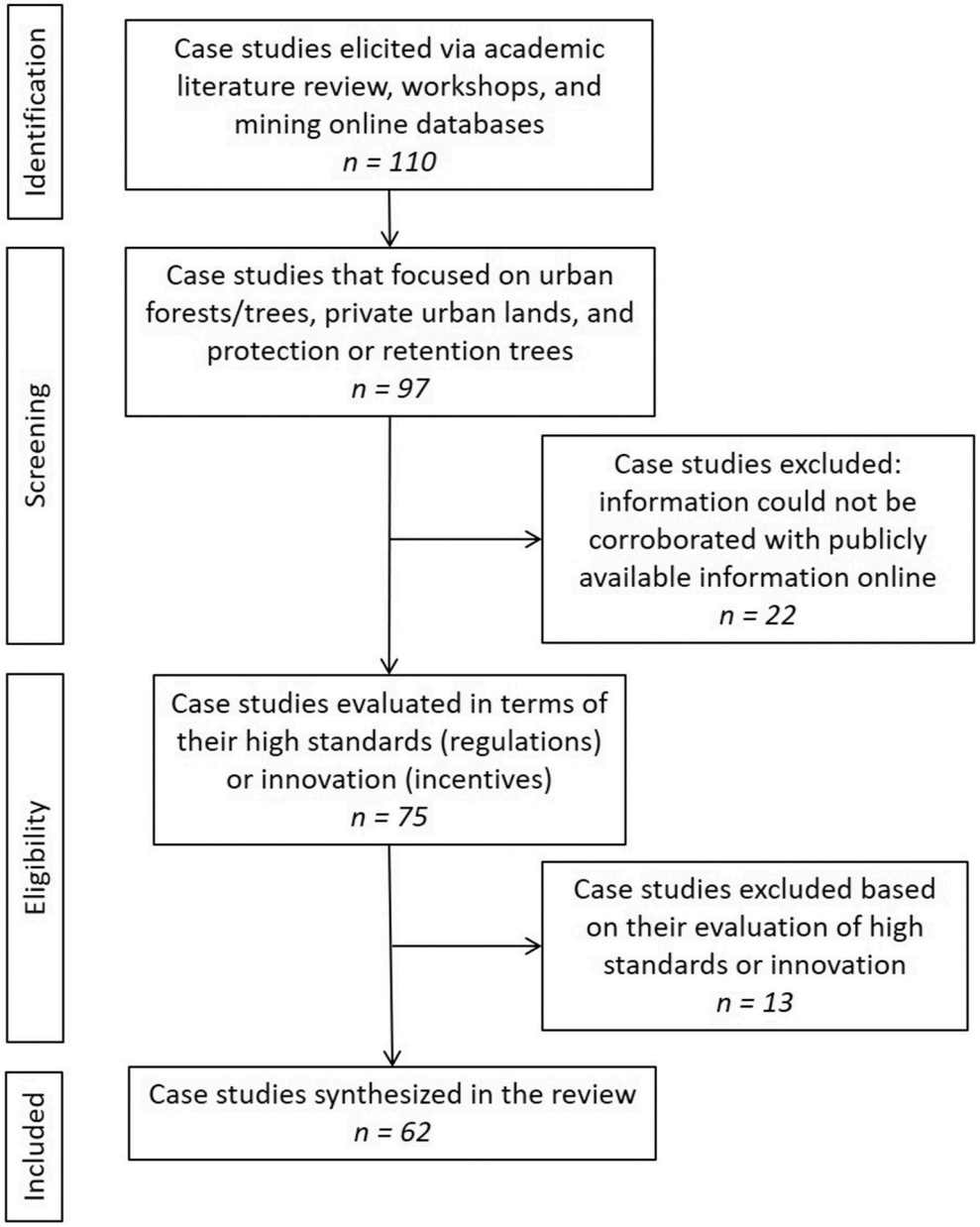

Fig. 3. Flowchart showing the results of the case study review.

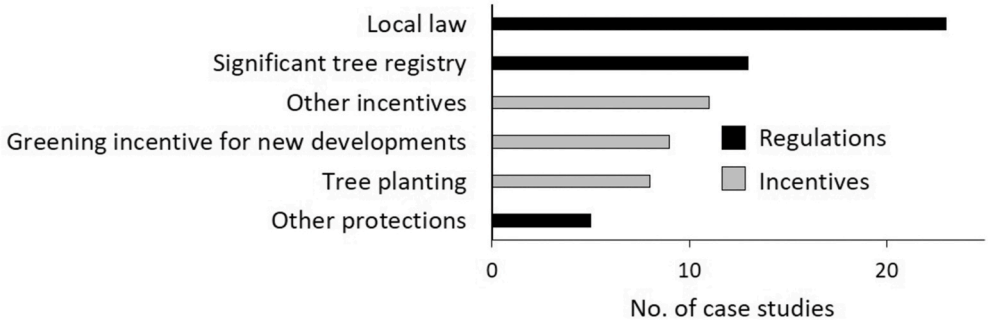

Fig. 4. Types of mechanisms included in the case studies reviewed (based on empirical data collected about case studies included in Supplementary Material 4).

language), all the while accounting for the different legal frameworks, governance structures, cultural norms, and land ownership laws in different countries. This would have resulted in a limited number of case studies and the likelihood of missing innovative case studies that did not fit these parameters.

We reviewed 110 potential case studies and selected 62 of these as innovative examples that could be corroborated with publicly available information (the full case study list is included in Supplementary Material 4; see Fig. 3). We characterized all the case studies using a similar, but more detailed, typology used for the incentives and regulations in the local study above (Fig. 4). None of our case studies came from international case study databases (Table 2; see notes in Supplementary Material 4). We recognize that there may be other innovative case studies out there that have not been included in our review. Rather than attempting to be exhaustive, or case study review is, at the very least, representative of the types of innovative mechanisms to protect and retain trees on private urban lands. Our review has some key strengths in that case studies were selected based on strict inclusion and exclusion criteria specifis to urban trees on private urban lands, with data sourced from a combination of a systematic literature review and the views of local and international urban forestry professionals. This gives us confidence that these case studies were specific and relevant to the topic.

4. Results

4.1. Academic literature

Most studies have reported a loss of canopy cover on private urban land, but some report a gain (Table 4). The key to understanding this literature is that canopy cover studies only assess net changes at large spatial scales (whole of city) and over a single period (between two measurement events). To contextualize observed net changes in canopy cover we need to consider previous land uses, the time frame chosen (Nowak and Greenfield 2020), and the fragmentation of canopy cover by land cover classifcations (Dobbs et al., 2013; Mincey et al., 2013; Vogt et al., 2015). Only a few studies have assessed the relationship between tree removal from private land and construction or re-development, mostly by using proxies, such as planning applications or the award of tree removal permits. There is a lack of data on the stated reasons for tree removal, which may include outgrowing (over-sized) the planted location, old age or over-maturity, the risk posed by the tree for humans or infrastructure, or the inconvenience the tree poses to construction activities (Guo et al., 2018).

Few countries unified regulations that apply to trees on private land across all cities. Yet, many cities in the US, Canada, Australia, and European countries have regulations that do not allow people to remove or alter these trees (Coughlin et al., 1988; Profus and Loeb, 1990; Dickerson et al., 2001; Schmied and Pillmann, 2003; Conway and Urbani, 2007; Watson, 2015; Hill et al., 2010). Most studies have identified and described the types of mechanisms that exist in different cities (Tables 1 and 4), but without evaluating them for their efficacy, efficiency, or innovation.

Urban forest professionals (municipal urban forest managers, other local government workers, arborists, and consultants) believe that stricter regulation combined with policies that stimulate more sustainable urban growth were effective at preserving trees than strict tree protection (Hill et al., 2010; Kirkpatrick et al., 2013). Sustainable urban growth is broadly defined as urban development policies that balance environmental, social, and economic objectives (UN, 2020).

Most homeowners and private residents have a positive attitude towards trees on their private land (e.g., Pearce et al., 2015; Avolio et al., 2018). These attitudes vary widely and depend on a person's knowledge of trees, recent gardening activity, and demographics, such as age, education level, and whether they rent or own the property (Dilley and Wolf, 2013; Avolio et al., 2018). These people are also aware of the perceived risks associated with trees, including fire, wind-throw and infrastructure damage (Kirkpatrick et al., 2012). In one study investigating people's attitudes towards regulatory mechanisms that required people to submit permits to remove or alter trees on private urban land (see Conway and Bang, 2014), most respondents did not support the regulation.

The efficacy of regulatory or incentive mechanisms in terms of how they may influence the number of trees and amount of canopy cover on private land has been difficult to assess. Some studies qualitatively assess the efficacy of regulations at the local level (e.g., Coughlin et al., 1988; Watson, 2015), but do not attach hard data to changes in tree number and canopy cover (Table 4). Nonetheless, most researchers have argued for discarding the specifications of size and species of trees to make regulations and incentives more effective, thus protecting all trees regardless of size or species (Coughlin et al., 1988; Hill et al., 2010; Kirkpatrick et al., 2013; Profus and Loeb, 1990; Watson, 2015). It is important to consider that, in some cases, such specifications are necessary (e.g., significant tree registries, species at risk, etc.). A more empirical approach involved assessing changes in tree numbers and/or canopy cover over two periods of time, before and after a mechanism were implemented, and comparing cities with and without this mechanism. Some studies using this approach have noted an increase or stabilisation of canopy cover in cities with tree regulations (Sung, 2012), wile others have observed that changes could be as much an effect of internal variations in the regulations than their actual efficacy (Conway and Urbani, 2007). This is because some tree regulations may be enshrined in planning schemes, while others may be simple guidelines, or because some cities may have a stronger enforcement capacity than others (Landry and Pu, 2010). Assessing the efficacy of tree protection

Table 4
Content of the academic literature about trees on private urban land (n = 43), including research domain and research themes (see Supplementary Material 1).

Research Domain	Research Theme	Study ID[a]
Abundance of tree numbers and canopy cover on private urban land	Patterns of tree and canopy cover loss and removal	4, 13, 20, 34, 35
	Patterns of tree and canopy cover increases and gains	3
	General patterns (no change assessment)	15, 28, 29
	Relationship between tree numbers or canopy cover loss/removal and development activity	9, 10, 17, 18, 27, 30, 39, 40,
Types of mechanisms to retain and protect trees on private land	Identification and description of existing regulations	36, 37
	Qualitative assessment of the efficacy of existing regulations	7, 9, 10, 12, 22, 42, 43
People's opinions about trees on private land	Opinion of private homeowners or residents reasons for tree planting	1, 2, 5, 6, 8, 14, 18, 23, 24, 38
	Opinion of urban forest professionals about private tree protection, conflicts, and reasons for tree planting	12, 19, 25, 31
Efficacy of mechanisms to retain and protect trees on private land	Increase of canopy cover between cities with and without tree protections	26, 41
	No difference of canopy cover between cities with and without tree protections	7, 41
Other Themes	Compensatory value formulas for tree removal on private land	11, 16, 32, 33

[a] For study ID, see Supplementary Material 1.

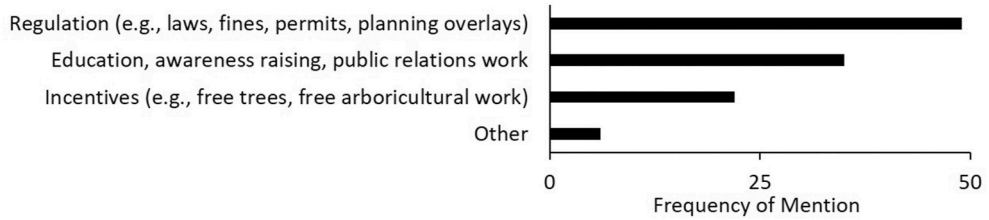

Fig. 5. The frequency of types of mechanisms for protecting or retaining trees on private urban land as mentioned by urban forest managers working in Victoria, Australia.

Fig. 6. The frequency of themes related to causes of tree loss, efficacy of tree protection, and tree protection opportunities on private urban land based on the social data collected from international urban forest professionals.

mechanisms is complex and influenced by many institutional, economic, and other external and context-specific factors.

4.2. Types of mechanisms

Most respondents of the online survey of Victorian local governments identified regulation as the most common mechanism to protect and retain trees on private urban land. This was followed by educational programs and incentives, including mostly free tree seedlings for plantings and free arboricultural maintenance work, rather than financial incentives as defined in Table 1. Other mechanisms that respondents identified ("other" in Fig. 5) included voluntary opportunities, such as voluntary tax incentive programs, as defined in Table 1, maintaining exceptional tree registries, and other tax rebates (e.g., "land sustainability rebate").

4.3. International perspectives

Workshop participants said that the most important causes of tree loss were planning policies that facilitated densification and development of private land. These policies conflicted with, or ignored, existing tree protection mechanisms. As a result, multi-dwelling development projects or private homeowners frequently removed trees from private land (these two activities coded as 'urban densification', Fig. 6). Participants frequently expressed their frustration and despair at the plight of urban trees on private land.

Suggestions for effectively protecting trees on private land included having the budget and personnel to review tree removal permit applications (budget concerns or human resources coded as 'resources'; Fig. 6). The variation in regulations among different metropolitan areas was also suggested as hindering the efficacy of tree protections. A less risk-averse culture in local governments and greater political will in these goverrnments to make unpopular decisions was raised as another

reason for tree protection success (Fig. 6).

Finally, rather than advocating for stricter laws, participants advocated for a comprehensive policy adjustment that could respond to urban densification, development, and growth that included consideration of trees and other vegetation. The importance of defining and providing better guidance for the protection of trees on 'transitional lands' was also mentioned. For example, sidewalks and rights of way are not well defined in new developments, and this causes conflicts with private landowners because they believe these areas are privately owned. For many participants, it was not so much that the mechanisms to protect trees on private land did not exist, but rather that local government officers were not able or willing to execute these mechanisms without community support.

4.4. Innovative case studies

Most reviewed case studies referred to regulation that prevented the removal of trees on private urban land, or financial incentives that encouraged the retention or planting of trees in new or re-developed sites (see details in Supplementary Material 4). The four most innovative cases are described below.

4.4.1. Comprehensive regulation in Seattle, US

Seattle's planning scheme shifts the responsibility for maintaining trees on private land to the city. The city relies on a combination of business as usual regulatory mechanisms to protect its trees on private land: a local law stipulates all trees of a certain size are to be protected, regardless of ownership or location; a registry of significant trees, compiled by nominations from residents (Young, 2011), offers protection based on size, biodiversity and cultural importance; zoning mechanisms define landscape types where the protections apply; and strict standards for building setbacks, define the percentage of land cover or area that trees need to survive (City of Seattle, 2018). It is the combination of mechanisms that makes the approach by Seattle innovative.

4.4.2. Tree bonds for private developments in Stonnington, Australia

5. The City of Stonnington in metropolitan Melbourne is implementing tree bonds on private land as a mechanism for protection. Tree bonds are used by many Australian cities, including Bendigo, Stirling, and Sydney (Supplementary Material 3), but only Stonnington applies them to private urban land (City of Stonnington, 2019). A tree bond requires a land developer to deposit a money guarantee with the local authority before starting development. The bonds apply to any tree deemed significant by the city. If the tree or trees are removed or damaged during works, the money is forfeited. The size of the bond reflects an estimated tree valuation that is set at a level likely to achieve compliance, usually in the range of thousands or tens of thousands of dollars (Hurley et al., 2018). Tree bonds are typically used for larger developments, such as multi-dwelling commercial or residential buildings.

4.4.3. Greening incentives for new developments

Several cities are developing tools allowing them to estimate the amount of greening that is required or recommended for new developments, and this effects trees on private land. Often called a green factor (e.g. Urban Greening Factor program, City of Seattle 2015; Green Factor, City of Helsinki 2014) or a green index (e.g. Green Area Ratio Index program, City of Washington DC, 2019), these tools calculate a score based on different green elements on a building site. Specific details vary, but they are based on the developers of new or re-developed sites obtaining tax rebates by calculating the amount of greening they are retaining or creating (Juhola, 2018). The aim is to incentivize private developers to pay attention not only to the types of green elements but also to the ecosystem services that the green elements provide.

In the case of stormwater runoff, for example, Portland's TreeBate Program (City of Portland, 2011; 2017) awards higher scores for retaining trees with a significant canopy cover or planting new trees, rather than planting grass. Seattle and Helsinki use similar systems. Washington DC values tree retention within the Green Area Ratio Index to reduce impervious surfaces in new developments (City of Washington DC, 2019).

These tools have not been fully evaluated yet, but experience to date shows they have shortcomings, including that institutional context may hinder their use (Juhola 2018). This is not surprising as developing tools for urban green infrastructure is challenging and results might not match the expectations of urban planners (van Oijstaeijen et al., 2020).

4.4.4. Tax benefits for protecting trees on private land in Hawaii, US

Hawaii's exceptional tree program was enacted in 1975 to protect the state's most valued trees from unnecessary removal and is managed by each of the four counties (Hawaii State Legislature, 1975). Exceptional trees can only be removed if they are deemed to be a threat to public safety (City of Honolulu, 2020), nor do they lose their protection if land ownership changes. While conservation programs of this nature are not unique, Hawaii's implementation of an incentive for private property owners is. In 2004, Hawaii's state legislature passed an amendment allowing private property owners to claim a tax deduction for designated exceptional trees (Hawaii State Legislature, 2004). Owners can claim $3000 per tree every three years to offset maintenance costs (Hawaii State Legislature, 2004). The aim is to improve the health of Hawaii's exceptional trees. So far, there is little information on the efficacy of the program, although, new research is underway to determine its impacts on the nomination process and continuing conservation of Hawaii's most valued trees.

5. Discussion & conclusion

Local governments play a significant role in regulating and influencing what happens to trees on private land. Their efforts will greatly determine their ability to meet ambitious tree canopy targets (Escobedo et al., 2008; McPherson et al., 2011; Ordóñez and Duinker, 2013; Plant et al., 2017; FAO, 2018; TNC, 2019; Nowak and Greenfield, 2020). Yet, there is no single simple solution to retain and protect trees on private urban land. Urban systems are complex with their own ecological and social characteristics. As such, it is impossible to advocate for incentives and against regulations, or vice versa. Rather, we believe that only a combination of both will work. This involves mixing policies, programs, resources, professionalism, education, values, leadership, and action with the aim of enhancing or at least maintaining the number of trees and extent of canopy cover on private urban land.

Our research has demonstrated that despite this being an issue of international concern, there is very little relevant academic research. For example, more research is needed to determine if existing mechanisms really do increase, or at least retain, trees and canopy cover on private urban land. In some ways, the mechanisms regarding trees on private land are an immature area of local government policy compared to other planning and environmental regulations, such as heritage protection (Bandarin and van Oers, 2012) or flood risk management (Alves et al., 2019). Nonetheless, our work also shows that many international urban forest professionals are collectively frustrated and exasperated at their inability to reduce the rate of tree loss from private land. While we have synthesized the most innovative approaches that are currently being used to protect and retain trees on private urban land, we do not know if these mechanisms are effective. As we have observed, their efficacy is highly dependent on local contexts.

In the following paragraphs we reflect on the advantages and disadvantages of regulatory and incentive mechanisms for protecting and retaining trees on private urban land. We also reflect on broader community issues. To conclude, we provide a set of guidelines evaluating and monitoring these regulatory and incentive mechanisms.

5.1. Advantages and disadvantages of regulations and incentives

Regulatory mechanisms will continue to be necessary for local governments to protect and retain trees on private urban land. These mechanisms describe and identify what is to be protected, give structure to policies and programs, and, in many cases, can be the main instrument for tree retention Yet, regulations add bureaucracy and costs to city governments, who have to process applications for tree removal permits and arborist reports (Currell, 2012; Hilbert et al., 2019). Moreover, a well-designed regulation is only as good as the accompanying system to enforce it. This includes the ability, professionalism, willingness, and resourcing capacity of the enforcement authority (Hill et al., 2010; Young, 2011; Lavy and Hagelman, 2019; Clark et al., 2020; van Oijstaeijen et al., 2020). In some ways, regulatory mechanisms that apply to trees on private urban land are an expression of what local governments find politically possible to do instead of what is the most effective thing to do (VLRC, 2017; Clark et al., 2020). Nonetheless, there are cities with innovative regulations, such as those based on a "pay first" principle, which provides an easier enforcement option. An example of these are tree bonds (see Results), which can be made even more effective by applying a time lag before bonds are repaid to ensure tree retention. Any funds raised through the retention of bonds, for example when tree protection measures are breached and the bond is kept by the local government, might help fund future tree protection, planting, or maintenance.

Despite the many instances of inadequate or ineffective tree protection from regulatory mechanisms (e.g., Coughlin et al., 1988; Watson, 2015, Table 4), there are still many success stories that should be examined to better understand the ingredients for success (e.g., Landry and Pu, 2010; Sung, 2012; VLRC, 2017; Pike et al., 2021, Table 4). But, most of these case studies focus on public tree protection (Hauer et al., 2020), having only evaluated the effectiveness of regulations in relation to changes in canopy cover over one period (Landry and Pu, 2010; Sung, 2012), or on the retention rate of specific trees on private land (Pike et al., 2021). These studies have not established the direct causal role of regulations in retaining a proportion of canopy cover over time, or evaluated the comparative effectiveness of different or similar regulation between local governments, or before and after a single local government established and applied a tree protection regulation. Ultimately, to improve this research we must find a way to decouple the specific type of mechanism being used from the ability of local governments to implement it (Conway and Urbani, 2007; Landry and Pu, 2010), as well as develop a clearer, more objective, or at least a more comparable subjective definition of what efficacy means, and perhaps more importantly, a framework as to how efficacy can be better evaluated (see Table 5).

Incentive mechanisms may be more desirable for many local governments because they reduce bureaucracy, often require less resource support, and do not promote an image of an overly intrusive government based on strict regulation. Promoting the preferred behavior can lead to less resistance than enforcing mandatory requirements. However, while academics have argued for decades for more incentives (e.g., Coughlin et al., 1988; Watson, 2015; Brown et al., 2018; FAO, 2018; Juhola, 2018; Clark et al., 2020), there is little evidence of their development, use or efficacy. Many local strategic documents on urban forests mention the importance of some of these incentives (e.g., tree awareness campaigns, adopt-a-tree programs for private homeowners; see Young, 2011; Ordóñez and Duinker, 2013), which aim to increase tree retention on private urban land. However, these lack the detail on how they are developed, operated, and monitored for their effectiveness. There is no information or monitoring as to whether they result in greater tree retention or canopy cover. Consequently, most research on incentives remains anecdotal. Our study has attempted to advance beyond this anecdotal evidence and evaluate incentive mechanisms for their innovation.

We believe innovative incentive mechanisms can help establish a paradigm shift for local governments, by reinforcing the value of trees and the responsibility of private landowners and other private stakeholders to take care of their trees, thus promoting community stewardship (Young, 2011; Boulton et al., 2018; Brown et al., 2018; Bush and Hes 2018). Our social science studies have shown that many urban forest professionals are already aware of the value of these mechanisms. For incentives to be effective, local governments should establish regulations that support them, avoid regulatory contradictions, and establish long term monitoring programs based on baselines (Juhola, 2018). These baselines may include locally-based tree valuations (e.g., Doick et al., 2018) or codifying the vegetation types to be retained (e.g., City of Washington DC, 2019). Incentives may also involve supporting citizen-led activities focused on planting or protecting trees on private land, and awarding prizes for volunteer activities (Young, 2011; Watson,

Table 5
Principles and criteria for evaluating and monitoring the usefulness and innovativeness of regulatory and incentive mechanisms for tree protection on private urban land.

Principle	Description and criteria
Multi-level government	Create consistent policy, management, and monitoring solutions that can be adopted at multiple levels of government (e.g., heritage protection strategies embedded at local and regional levels).
Embed trees early on	Embed urban trees and their long-term presence as a specific solution early in existing strategic policy or management solutions (e.g., heritage protection embedded in the development process).
Include trees in the discourse	Recognize the co-benefits of trees in already existing or future strategic policy or management solutions (e.g., trees associated with cultural identity).
Incentivize positive behavior	Create solutions that incentivize positive behaviour rather than penalize negative behavior. This means creating mechanisms that stimulate the retention or maintenance of existing trees, or the planting of new trees, rather than penalizing the removal of existing trees (e.g., green index and point-based systems for new developments or renewals; tax rebates for maintain trees).
Use multiple tools	Create solutions involving a combination of regulations and incentives, and a mix of policies, programs, resources, education, engagement, leadership, and action (e.g., combination of local laws, registry of significant trees, arboricultural repors, professional qualifications system for arborists, zoning or overlays, and standards or certification programs that specify tree management recommendations for developments).
Pay first	Create mechanisms that require tree compensation to be paid prior to the activity (e.g., tree bonds).
Economically value trees	Create mechanisms that calculate the economic, environmental, amenity and financial replacement value of urban trees. These formulas demand compensation, such as tree bonds, or incentivize positive behavior, such as retaining trees on new developments or private residences (e.g., amenity value formulas).
Support the community	Create a comprehensive and proactive community engagement program, which involves a communications plan, establishing a communications officer position, creating programs to celebrate and award the private stewardship of trees, and support citizen-led activities through funds, co-management agreements, and/or logistical support.
Monitor efficacy and efficiency	Develop a monitoring program to track the efficacy and efficiency of individual regulatory or incentive mechanisms over the long term. Criteria may include: - Effect of the mechanism on the number of trees and/or amount of canopy cover (must include baseline data, change over time, in comparable cities or areas of an urban area with and without the same mechanism). - Effect of a mechanism on resources, including personnel and budgets. - Effect of mechanism on educational (e.g., level of tree knowledge), psychological (e.g., level of tree awareness or satisfaction), or social (e.g., number of volunteers) indicators.

2015; Daniel et al., 2016; Bush and Hes 2018; Buijs et al., 2019).

Finally, even in cases where innovative mechanisms are implemented, cities may still experience urban forest loss and removal. This is because of the impact of urban development (e.g., Hurley et al., 2019; Nowak and Greenfield, 2020), the reduced performance of trees due to the challenging and constantly changing growing conditions (Vogt et al., 2015), and, just as important, their senescence. Therefore, replacement strategies are as important in protecting and retaining urban trees as implementing regulatory and incentive mechanisms. Without plans to replace trees, the space previously occupied by a large tree may provide new land for urban development, and this can further undermine our capacity to protect the urban forest. The soil, root system, and canopy of the space must also be accounted for.

5.2. The role of community

Protecting and retaining trees on private urban land is not just a technical issue to be solved by local governments. There is also a need for understanding broader community issues, including people's perceptions of urban trees and regulations/incetives, community engagement, as well as community stewardship and behaviour change.

To engage the community and promote stewardship, we must first understand the public's perception of urban trees, and this includes trees not just on a landowner's property but also trees on other people's private land. This has not yet been investigated. Empirical research in this area has shown that most people have a positive attitude towards street trees (Schroeder et al., 2006) and a negative attitude towards existing regulations that require people to apply for a permit to remove a tree (Conway & Bang; 2014; Conway and Lue, 2018). However, these attitudes vary by context (e.g, private vs. public trees) and demographics (e.g., homeowner vs. tenant; see Dilley and Wolf, 2013; Conway & Bang; 2014; Avolio et al., 2018). This is because social perceptions of trees are not monolithic and are expressed in various ways, from variable and less stable attitudes and preferences, to deeply held and more stable beliefs and values (Pearce et al., 2015). In other words, while most people value urban trees and believe positive things about them, some people may still hold negative attitudes and preferences about specific trees or specific regulations/incentives. Such variable attitudes and preferences should not be generalized or extrapolated to apply to all trees, all people, and all contexts over time (Roman et al., 2020), but rather used reasonably to guide urban forest and tree management.

Local governments should proactively engage with their communities in order to promote stewardship and behavioural change. Some innovative ways to do this include engaging with the private development and landowning sector to better implement regulatory mechanisms (TNC, 2017; Brown et al., 2018). Tailoring urban forestry messages to specific audiences may help build trust with local government (Thostenson et al., 2018). Developing agreements with residents on maintenance strategies has been successful for public trees (Mincey and Vogt, 2014), but its application to private trees is unclear. Understanding how people in the community perceive risks related to urban trees as compared to professionals may help reduce the institutional bias of reducing tree risk by all means necessary, a main driver for urban forest loss (see Klein et al., 2019; Hersh et al., 2019; Clark et al., 2020). Integrating public perception and participation into urban forestry activities, from strategic planning (Ordóñez and Duinker, 2013; Brown et al., 2018) to tree-planting campaigns (Carmichael and McDonough, 2019), is key to the success of these activities. Local governments can also play a key role in supporting citizen-led initiatives, such as arranging the co-management of trees (e.g., van der Jagt et al., 2019) or supporting community-based initiatives (Bush and Hes 2018; Buijs et al., 2019). It is useful to note here that while such activities have an important social impact, such as improving participation and stewardship, more research is needed to understand their actual impact on tree numbers and canopy cover.

5.3. Evaluating and monitoring regulatory and incentive mechanisms

Given that there is no global standard for evaluating and monitoring the utility and innovation of regulations and incentives, we have developed a framework to do this based on a set of principles and criteria (Table 5). We recognize that this framework could be overly prescriptive and fail to consider the specific needs and contexts of local governments. Indeed, some local governments have already undertaken significant empirical investigations to formulate their own solutions to protect and retain trees on private urban land (e.g., City of Melbourne, 2011). Also, most innovative mechanisms are relatively new, and as such their efficacy will be difficult to measure. We recognize that there are underlying political, social, and geographical assumptions behind this framework, including the fact that we interpret private urban land through westernised legal frameworks (see DeRudder, 2006; Taylor et al., 2006), which may not apply in other contexts (see Jim and Liu, 2000; Jim, 2004). Also, our views are framed by what might be effective in rapidly densifying cities. Nonetheless, developing a framework is still valuable and we believe a key contribution to future research and understanding about the issues of tree protection on private land. It can help us define how efficacy and efficiency may be evaluated, without being overly prescriptive. It can also help us understand whether mechanisms are useful in a wide range of contexts and situations. More practically, a framework can provide a more informed environment in which local governments can decide what they want to do, without denying them the chance to tailor criteria of evaluation and monitoring to their own purposes.

Author statement of contributions

Authors CO, JB, JH, MA, SJL, SF, AE, KH, and MC contributed to the conception and design of the research study. CO, CC, JB, JH, MA, and SJL conducted the academic research, including development of methodology, data collection, data curation, and formal analyses. CO led and undertook all social science data collection and analysis. CO, JB, JH, MA, and SJL led the writing of the manuscript, with significant contributions from CC, MR, SJ, SF, AE, MC, and SW for interpretation, critical reviews, editing, and intellectual content. All authors contributed critically to the drafts and gave final approval for publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

Alves, A., Gersonius, B., Kapelan, Z., Vojinovic, Z., Sanchez, A., 2019. Assessing the co-benefits of green-blue-grey infrastructure for sustainable urban flood risk management. J. Environ. Manag. 239, 244–254. https://doi.org/10.1016/j.jenvman.2019.03.036.

Avolio, M.L., Pataki, D.E., Trammell, T.L., Endter-Wada, J., 2018. Biodiverse cities: the nursery industry, homeowners, and neighborhood differences drive urban tree composition. Ecol. Monogr. 88, 259–276. https://doi.org/10.1002/ecm.1290.

Bandarin, F., van Oers, R., 2012. The Historic Urban Landscape: Managing Heritage in an Urban Century. Wiley-Blackwell, John Wiley & Sons, Oxford, UK.

Boulton, C., Dedekorkut-Howes, A., Byrne, J., 2018. Factors shaping urban greenspace provision: a systematic review of the literature. Landsc. Urban Plann. 178, 82–101. https://doi.org/10.1016/j.landurbplan.2018.05.029.

Brown, H., Proust, K., Newell, B., Spickett, J., Capon, T., Bartholomew, L., 2018. Cool Communities—urban density, trees, and health. Int. J. Environ. Res. Publ. Health 15, 1547. https://doi.org/10.3390/ijerph15071547.

Buijs, A., Hansen, R., van der Jagt, S., Ambrose-Oji, B., Elands, B., Lorance-Rall, E., Mattijssen, T., Pauleit, S., Runhaar, H., Stahl-Olafsson, A., Steen-Møller, M., 2019. Mosaic governance for urban green infrastructure: upscaling active citizenship from a local government perspective. Urban For. Urban Gree. 40, 53–62. https://doi.org/10.1016/j.ufug.2018.06.011.

Bush, J., 2020. The role of local government greening policies in the transition towards nature-based cities. Environ. Innov. Soc. Tr. 35, 35–44. https://doi.org/10.1016/j.eist.2020.01.015.

Bush, J., Hes, D., 2018. Urban green space in the transition to the eco-city: policies, multifunctionality and narrative. In: Hes, D., Bush, J. (Eds.), Enabling Eco-Cities – Defining, Planning and Creating a Thriving Future. Palgrave, Singapore, pp. 43–64.

Carmichael, C.E., McDonough, M.H., 2019. Community stories: explaining resistance to street tree-planting programs in Detroit, Michigan, USA. Soc. Nat. Resour. 32, 588–605. https://doi.org/10.1080/08941920.2018.1550229.

City of Helsinki, 2014. Helsingin Viherkerroinmenetelmä. Käyttöohje. Helsingin kaupunki, Helsinki. Retrieved from. https://www.hel.fi/static/rakvv/lomakkeet/viherkerroin-kayttoohje.pdf. May 2020.

City of Honolulu, 2020. Article 13: Protective Regulations for Exceptional Trees. Retrieved from. https://www.honolulu.gov/rep/site/ocs/roh/ROH_Chapter_41a1-25_.pdf. May 2020.

City of Melbourne, 2011. Future Melbourne Committee Report. Retrieved from. www.melbourne.vic.gov.au/about-council/committees-meetings/meeting-archive/MeetingAgendaItemAttachments/530/8949/5.2.pdf. Dec 2019.

City of Portland, 2011. City Wide Tree Policy and Review. Retrieved from. https://www.portlandoregon.gov/bps/article/331401. Oct 2019.

City of Portland, 2017. TreeBate Program. Retrieved from. https://www.portlandoregon.gov/bes/51399. Oct 2019.

City of Seattle, 2015. Seattle Green Factor. Seattle, WA, US, Retrieved from. http://www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/seattle-green-factor. Oct 2019.

City of Seattle, 2018. Tree Protection Regulation Review. City of Seattle, Seattle, WA, US. Retrieved from. https://www.seattle.gov/Documents/Departments/UrbanForestryCommission/Resources/Final%20Report_Tree%20Regulation%20Research%20ProjectPahseII_31MAR2017_final.pdf. Oct 2019.

City of Stonnington, 2019. Council Tree Maintenance. Retrieved from. https://www.stonnington.vic.gov.au/Live/Trees-in-Stonnington/Trees-on-public-land/Council-Tree-Maintenance. Oct 2019.

City of Washington D.C., 2019. Green Area Ratio. Retrieved from. https://doee.dc.gov//sites/default/files/dc/sites/ddoe/page_content/attach. Oct 2019.

Clark, C., Ordóñez, C., Livesley, S.J., 2020. Private tree removal, public loss: valuing and enforcing existing tree protection mechanisms is the key to retaining urban trees on private land. Landsc. Urban Plann. 203, 103899. https://doi.org/10.1016/j.landurbplan.2020.103899.

Conway, T.M., Bang, E., 2014. Willing partners? residential support for municipal urban forestry policies. Urban For. Urban Gree. 13, 234–243. https://doi.org/10.1016/j.ufug.2014.02.003.

Conway, T., Lue, A., 2018. Resident knowledge and support for private tree by-laws in the Greater Toronto Area. Arboric. Urban For. 44, 185–200.

Conway, T.M., Urbani, L., 2007. Variations in municipal urban forestry policies: a case study of Toronto, Canada. Urban For. Urban Gree. 6, 181–192. https://doi.org/10.1016/j.ufug.2007.07.003.

Corbin, J., Strauss, A.L., 2015. Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory. Sage Publications, Thousand Oaks, CA, USA.

Coughlin, R.E., Mendes, D.C., Strong, A.L., 1988. Local programs in the United States for preventing the destruction of trees on private land. Landsc. Urban Plann. 15, 165–171. https://doi.org/10.1016/0169-2046(88)90024-2.

Creswell, J.W., 2017. Qualitative Inquiry and Research Design: Choosing Among Five Approaches, fourth ed. Sage Publications Inc., Thousand Oaks, CA, USA.

Currell, A., 2012. Reviewing tree preservation orders: implications for local planning authorities. Arboric. J. 28, 21–43. https://doi.org/10.1080/03071375.2004.9747400.

Daniel, C., Morrison, T.H., Phinn, S., 2016. The governance of private residential land in cities and spatial effects on tree cover. Environ. Sci. Pol. 62, 79–89. https://doi.org/10.1016/j.envsci.2016.01.015.

DeRudder, B., 2006. On conceptual confusion in empirical analyses of a transnational urban network. Urban Stud. 43, 2027–2046. https://doi.org/10.1080/00420980600897842.

Dickerson, S.D., Groninger, J.W., Mangun, J.C., 2001. Influences of community characteristics on municipal tree ordinances in Illinois, US. J. Arboric. 27, 318–325.

Dilley, J., Wolf, K.L., 2013. Homeowner interactions with residential trees in urban areas. Arboric. Urban For. 39, 267–277.

Dillman, D.A., Smyth, J.D., Christian, L.M., 2014. Internet, Phone, Mail, and Mixed-Mode Surveys: the Tailored Design Method, fourth ed. John Wiley & Sons, Inc., Hoboken, NJ, US.

Dixon-Woods, M., Agarwal, S., Jones, D., Young, B., Sutton, A., 2005. Synthesising qualitative and quantitative evidence: a review of possible methods. J. Health Serv. Res. Pol. 10, 45–53. https://doi.org/10.1177/135581960501000110.

Dobbs, C., Kendal, D., Nitschke, C., 2013. The effects of land tenure and land use on the urban forest structure and composition of melbourne. Urban For. Urban Gree. 12, 417–425. https://doi.org/10.1016/j.ufug.2013.06.006.

Doick, K.J., Neilan, C., Jones, G., Allison, A., McDermott, I., Tipping, A., Haw, R., 2018. CAVAT (capital asset value for amenity trees): valuing amenity trees as public assets. Arboric. J. 40, 67–91. https://doi.org/10.1080/03071375.2018.1454077.

Escobedo, F.J., Wagner, J.E., Nowak, D.J., la Maza, C.L., Rodriguez, M., Crane, D.E., 2008. Analyzing the cost effectiveness of Santiago, Chile's policy of using urban forests to improve air quality. J. Environ. Manag. 86, 148–157. https://doi.org/10.1016/j.jenvman.2006.11.029.

FAO, 2018. Forests and Sustainability Cities - Inspiring Stories from Around the World. FAO, UN, Rome, Italy. Retrieved from. http://www.fao.org/3/I8838EN/i8838en.pdf. Oct 2019.

Guo, T., Morgenroth, J., Conway, T., 2018. Redeveloping the urban forest: the effect of redevelopment and property-scale variables on tree removal and retention. Urban For. Urban Gree. 35, 192–201. https://doi.org/10.1016/j.ufug.2018.08.012.

Hauer, R.J., Koeser, A.L., Parbs, S., Kringer, J., Krouse, R., Ottman, K., Miller, R.W., Sivyer, D., Timilsina, N., Werner, L.P., 2020. Long-term effects and development of a tree preservation program on tree condition, survival, and growth. Landsc. Urban Plann. 193, 103670. https://doi.org/10.1016/j.landurbplan.2019.103670.

Hawaii State Legislature, 1975. Act 105. Environmental Quality. Retrieved from. https://www.capitol.hawaii.gov/slh/Years/SLH1975/SLH1975_Act105.pdf. May 2020.

Hawaii State Legislature, 2004. Bill: Exceptional Trees, Tax Deduction. Bill No. 1848, 22nd Legislature Registered Session. Retrieved from. https://www.capitol.hawaii.gov/session2004/bills/HB1848_CD1_.htm. May 2020.

Hersh, J., Martin, D.G., Geron, N.B., Rogan, J., 2019. A relational theory of risk: a case study of the asian longhorned beetle infestation in worcester, MA. J. Risk Res. 23, 781–795. https://doi.org/10.1080/13669877.2019.1628091.

Hilbert, D.R., Koeser, A.K., Roman, L.A., Hamilton, K., Landry, S.M., Hauer, R.J., Campanella, H., McLean, D., Andreu, M., Perez, H., 2019. Development practices and ordinances predict inter-city variation in Florida urban tree canopy coverage. Landsc. Urban Plann. 190, 103603. https://doi.org/10.1016/j.landurbplan.2019.103603.

Hill, E., Dorfman, J.H., Kramer, E., 2010. Evaluating the impact of government land use policies on tree canopy coverage. Land Use Pol. 27, 407–414. https://doi.org/10.1016/j.landusepol.2009.05.007.

Hurley, J., Kendal, D., Bush, J., Rowley, S., 2018. How tree bonds can help preserve the urban forest. Retrieved from. https://theconversation.com/how-tree-bonds-can-help-preserve-the-urban-forest-93420. Oct 2019.

Hurley, J., Saunders, A., Both, A., Sun, C., Boruff, B., Duncan, J., Amati, M., Caccetta, P., 2019. Urban Vegetation Cover Change in Melbourne 2014 - 2018. RMIT University, Melbourne, VIC, Australia. Retrieved from. https://cur.org.au/cms/wp-content/uploads/2019/07/urban-vegetation-cover-change.pdf. Jul 2019.

Jim, C.Y., 2004. Evaluation of heritage trees for conservation and management in Guangzhou city (China). Environ. Manag. 33, 74–86. https://doi.org/10.1007/s00267-003-0169-0.

Jim, C.Y., Liu, H.H.T., 2000. Statutory measures for the protection and enhancement of the urban forest in Guangzhou city, China. Forestry 73, 311–329. https://doi.org/10.1093/forestry/73.4.311.

Juhola, S., 2018. Planning for a green city: the green factor tool. Urban For. Urban Gree. 34, 254–258. https://doi.org/10.1016/j.ufug.2018.07.019.

Kirkpatrick, J.B., Davison, A., Daniels, G.D., 2012. Resident attitudes towards trees influence the planting and removal of different types of trees in eastern australian cities. Landsc. Urban Plann. 107, 147–158. https://doi.org/10.1016/j.landurbplan.2012.05.015.

Kirkpatrick, J.B., Davison, A., Harwood, A., 2013. How tree professionals perceive trees and conflicts about trees in Australia's urban forest. Landsc. Urban Plann. 119, 124–130. https://doi.org/10.1016/j.landurbplan.2013.07.009.

Klein, R.W., Koeser, A.K., Hauer, R.J., Hansen, G., Escobedo, F.J., 2019. Risk assessment and risk perception of trees: a review of literature relating to arboriculture and urban forestry. Arboric. Urban For. 45, 23–33.

Konijnendijk, C.C., Ricard, R.M., Kenney, A., Randrup, T.B., 2006. Defining urban forestry-A comparative perspective of north America and europe. Urban For. Urban Gree. 4, 93–103. https://doi.org/10.1016/j.ufug.2005.11.003.

Landry, S., Pu, R., 2010. The impact of land development regulation on residential tree cover: an empirical evaluation using high-resolution IKONOS imagery. Landsc. Urban Plann. 94, 94–104. https://doi.org/10.1016/j.landurbplan.2009.08.003.

Lavy, B.L., Hagelman III, R.R., 2019. Protecting the urban forest: variations in standards and sustainability dimensions of municipal tree preservation ordinances. Urban For. Urban Gree. 44, 126394. https://doi.org/10.1016/j.ufug.2019.126394.

Lawrence, A., De Vreese, R., Johnston, M., Konijnendijk van den Bosch, C.C., Sanesi, G., 2013. Urban forest governance: towards a framework for comparing approaches. Urban For. Urban Gree. 12, 464–473. https://doi.org/10.1016/j.ufug.2013.05.002.

Le Roux, D.S., Ikin, K., Lindenmayer, D.B., Blanchard, W., Manning, A.D., Gibbons, P., 2014. Reduced availability of habitat structures in urban landscapes: implications for policy and practice. Landsc. Urban Plann. 125, 57–64. https://doi.org/10.1016/j.landurbplan.2014.01.015.

Maddison, S., Denniss, R., 2013. An Introduction to Australian Public Policy: Theory and Practice, second ed. Cambridge University Press, Port Melbourne, Victoria, Australia.

McPherson, E.G., Simpson, J.R., Xiao, Q., Wu, C., 2011. Million trees los angeles canopy cover and benefit assessment. Landsc. Urban Plann. 99, 40–50. https://doi.org/10.1016/j.landurbplan.2010.08.011.

Mincey, S.K., Vogt, J.M., 2014. Watering strategy, collective action, and neighborhood-planted trees: a case study of indianapolis, Indiana, U.S. Arboric. Urban For. 40 (2), 84–95.

Mincey, S.K., Schmitt-Harsh, M., Thurau, R., 2013. Zoning, land use, and urban tree canopy cover: the importance of scale. Urban For. Urban Gree. 12, 191–199. https://doi.org/10.1016/j.ufug.2012.12.005.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J. Clin. Epidemiol. 62, 1006–1012. https://doi.org/10.1016/j.jclinepi.2009.06.005.

Mumaw, L., 2017. Transforming urban gardeners into land stewards. J. Environ. Psychol. 52, 92–103. https://doi.org/10.1016/j.jenvp.2017.05.003.

Nowak, D.J., Greenfield, E.J., 2020. The increase of impervious cover and decrease of tree cover within urban areas globally (2012–2017). Urban For. Urban Gree. 49, 126638. https://doi.org/10.1016/j.ufug.2020.126638.

Ordóñez, C., Duinker, P.N., 2013. An analysis of urban forest management plans in Canada: implications for urban forest management. Landsc. Urban Plann. 116, 36–47. https://doi.org/10.1016/j.landurbplan.2013.04.007.

Pearce, L.M., Davison, A., Kirkpatrick, J.B., 2015. Personal encounters with trees: the lived significance of the private urban forest. Urban For. Urban Gree. 14, 1–7. https://doi.org/10.1016/j.ufug.2014.11.003.

Pike, K., O'Herrin, K., Klimas, C., Vogt, J., 2021. Tree preservation during construction: an evaluation of a comprehensive municipal tree ordinance. Urban For. Urban Green. 57, 126914. https://doi.org/10.1016/j.ufug.2020.126914.

Plant, L., Rambaldi, A., Sipe, N., 2017. Evaluating revealed preferences for street tree cover targets: a business case for collaborative investment in leafier streetscapes in Brisbane, Australia. Ecol. Econ. 134, 238–249. https://doi.org/10.1016/j.ecolecon.2016.12.026.

Profus, G.V., Loeb, R.E., 1990. The legal protection of urban trees: a comparative world survey. J. Environ. Law 2, 179–193.

Pullin, A.S., Stewart, G.B., 2006. Guidelines for systematic review in conservation and environmental management. Conserv. Biol. 20, 1647–1656. https://doi.org/10.1111/j.1523-1739.2006.00485.x.

Ritchie, M., 2019. Establishing Consensus Core Criteria for the Protection of Heritage Trees. University of Hawai'i at Mānoa, Mānoa, HI, US. Retrieved from. https://scholarspace.manoa.hawaii.edu/handle/10125/66238. (Accessed March 2020).

Roman, L.A., Conway, T.M., Eisenman, T.S., Koeser, A.K., Barona, C.O., Locke, D.H., Jenerette, G.D., Östberg, J., Vogt, J., 2020. Beyond 'trees are good': disservices, management costs, and tradeoffs in urban forestry. Ambio 1–16. https://doi.org/10.1007/s13280-020-01396-8.

Rowley, S., 2017. The Victorian Planning System: Practice, Problems and Prospects. The Federation Press, Leichhardt, NSW, Australia.

Schmied, A., Pillmann, W., 2003. Tree protection legislation in european cities. Urban For. Urban Gree. 2, 115–124. https://doi.org/10.1078/1618-8667-00028.

Schroeder, H., Flannigan, J., Coles, R., 2006. Residents' attitudes toward street trees in the UK and U.S. communities. Arboric. Urban For. 32, 236–246.

Sung, C.Y., 2012. Evaluating the efficacy of a local tree protection policy using LiDAR remote sensing data. Landsc. Urban Plann. 104, 19–25. https://doi.org/10.1016/j.landurbplan.2011.09.009.

Taylor, P., DeRudder, B., Saey, P., Witlox, F., 2006. Cities in Globalization: Practices, Policies and Theories. Routledge, London, UK.

Thostenson, K., Witzling, L., Shaw, B., Gorby-Knoot, T., 2018. Communicating More Effectively about Urban Forestry. Wisconsin Department of Natural Resources, University of Wisconsin, Madison, WI, US. Retrieved from. https://forestryinsights.org/files/2018/04/Urban-Forestry-Report.pdf. May 2020.

TNC, 2017. Funding Trees for Health - an Analysis of Finance and Policy Actions to Enable Tree Planting for Public Health. The Nature Conservancy (TNC), Washington, DC, US. Retrieved from. https://www.nature.org/content/dam/tnc/nature/en/documents/Trees4Health_FINAL.pdf. Aug 2019.

TNC, 2019. Living Melbourne: Our Metropolitan Urban Forest - the Strategy. The Nature Conservancy (TNC), Melbourne, VIC, Australia, p. 82. Retrieved from: https://resilientmelbourne.com.au/living-melbourne/. Jan 2021.

Troy, A.R., Grove, J.M., O'Neil-Dunne, J.P., Pickett, S.T., Cadenasso, M.L., 2007. Predicting opportunities for greening and patterns of vegetation on private urban lands. Environ. Manag. 40, 394–412. https://doi.org/10.1007/s00267-006-0112-2.

UN, 2020. Sustainable Development Goals Report. United Nations (UN) Department of Economic and Social Affairs, Geneva, Switzerland. Retrieved from: https://unstats.un.org/sdgs/report/2020/. Dec 2020.

van der Jagt, A.P.N., Smith, M., Ambrose-Oji, A., Konijnendijk, C., Giannico, V., Haase, D., Lafortezza, R., Nastran, M., Pintar, M., Železnikar, Š., Cvejić, R., 2019. Co-creating urban green infrastructure connecting people and nature: a guiding framework and approach. J. Environ. Manag. 233, 757–767. https://doi.org/10.1016/j.jenvman.2018.09.083.

van Oijstaeijen, W., Van Passel, S., Cools, J., 2020. Urban green infrastructure: a review on valuation toolkits from an urban planning perspective. J. Environ. Manag. 267, 110603. https://doi.org/10.1016/j.jenvman.2020.110603.

Victoria Planning Authority, 2018. Know Your Council. Retrieved from: http://knowyourcouncil.vic.gov.au/councils. Aug 2019.

VLRC, 2017. Neighbourhood Tree Disputes: Consultation Paper. Victorian Law Reform Commission (VLRC), Melbourne, VIC, Australia, p. 138. Retrieved from: www.lawreform.vic.gov.au. Dec 2019.

Vogt, J.M., Watkins, S.L., Mincey, S.K., Patterson, M.S., Fischer, B.C., 2015. Explaining planted-tree survival and growth in urban neighborhoods: a social–ecological approach to studying recently-planted trees in indianapolis. Landsc. Urban Plann. 136, 130–143. https://doi.org/10.1016/j.landurbplan.2014.11.021.

Watson, J., 2015. Preserving tomorrow's urban trees with financial incentives: the choice of a new (tree) generation. Alternative Law J. 40, 261–265. https://doi.org/10.1177/1037969X1504000410.

Young, R.F., 2011. Planting the living city best practices in planning green infrastructure-results from major U.S. cities. J. Am. Plann. Assoc. 77, 368–381. https://doi.org/10.1080/01944363.2011.616996.

Zuniga-Teran, A.A., Staddon, C., de Vito, L., Gerlak, A.K., Ward, S., Schoeman, Y., Hart, A., Booth, G., 2020. Challenges of mainstreaming green infrastructure in built environment professions. J. Environ. Plann. Manag. 63, 710–732. https://doi.org/10.1080/09640568.2019.1605890.