INTERNATIONAL APPROACHES TO PROTECTING AND RETAINING TREES ON PRIVATE URBAN LAND

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Highlights

- We provide a global outlook on protecting and retaining trees on private urban land
- We used literature and case study reviews, and views of international urban forest professionals
- Innovative cities combined policies, planning schemes, local laws, and financial incentives
- Incentivising positive behavior and implementing a “pay first” principle may be useful
- Engaging community and fostering collective stewardship is key

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.

Keywords: municipal government; urban planning; urban forest management; nature-based solutions; private land; private property

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 & Greenfield, 2020; FAO, 2018). Many major world cities are undertaking ambitious 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 & 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 & Loeb, 1990; Conway & Urbani, 2007; Hilbert et al., 2019; Lavy & 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 circumstances, local governments can still bring private landowners to court for not abiding to, for example, tree removal regulations or guidelines for private property development that include tree 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 & Loeb, 1990; Schmied & Pillmann, 2003; Conway & 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 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 & Pillmann, 2003; Lawrence et al., 2013; US, see Coughlin et al., 1988; Watson, 2015; Canada, see Conway & 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 & Loeb, 1990; Schmied & Pillmann,

2003; Clark et al., 2020). Jurisdictions that use local laws to regulate trees on private urban land include US (Landry & Pu, 2010; Sung, 2012; Watson, 2015), Canada (Conway & Urbani, 2007), most European countries (Profus & Loeb, 1990; Schmied & Pillmann, 2003), Australia (Kelly, 2014), and China (Jim & 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 & 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 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 & Urbani, 2007; Landry & 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 & Hes 2018). For many years, the default incentive of many local governments was the provision of free tree seedlings for private landowners to plant, or public education campaigns highlighting the importance of urban trees (Ordóñez & 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 & 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 & 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 & 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 & Urbani, 2007; Landry & Pu, 2010; Lavy & 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 & 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).

179 *Table 1:* Framework for characterizing regulatory and incentive mechanisms for tree protection
180 and retention on private urban land as business-as usual (BAU) or innovative (based on data
181 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*	Protection as BAU approach but that applies specifically to private land; does not discriminate based on tree size or species; and uses compensatory tree valuation formulas*
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* 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; requires payment in advance as an investment or bond; and uses compensatory tree valuation formulas*
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
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; and the rebate or grant is calculated via compensatory tree valuation formulas*
* Compensatory value formulas are usually specific to the area (see Doick et al., 2018)			

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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 (Figure 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).

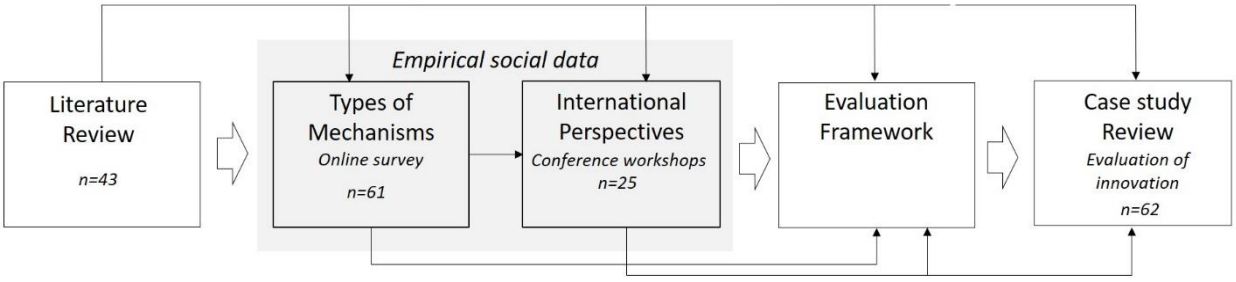

Figure 1: Stages and procedures of this research and their relationships, indicating number of articles for literature review, respondents or participants for empirical social data, and case study cities for case study review

3.1 Systematic Literature Review

Following the systematic review guidelines by Pullin & 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 and Figure 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.

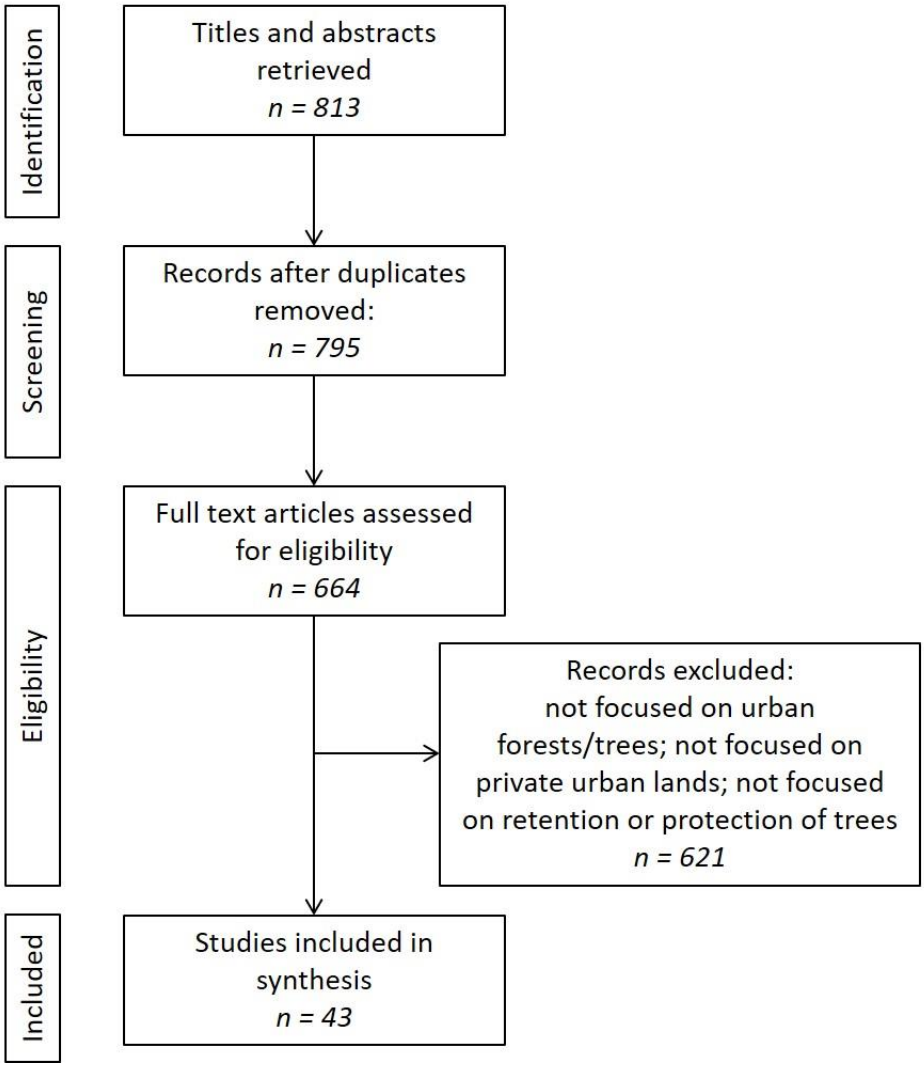

Figure 2: Flowchart showing the results of the systematic academic literature review

257 *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 <u>Databases used:</u> *Scopus* *Web of Science* <u>Non-indexed Individuals Journals used:</u> *Arboriculture and Urban Forestry;* *Arboricultural Journal*	<u>Keywords used*:</u> 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 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
* Bolean operators such as AND OR were used in between groups to include or exclude words in the search		

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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 (Figure 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 & 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 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 & 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 & 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 (Figure 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' (Figure 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 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., 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). 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.

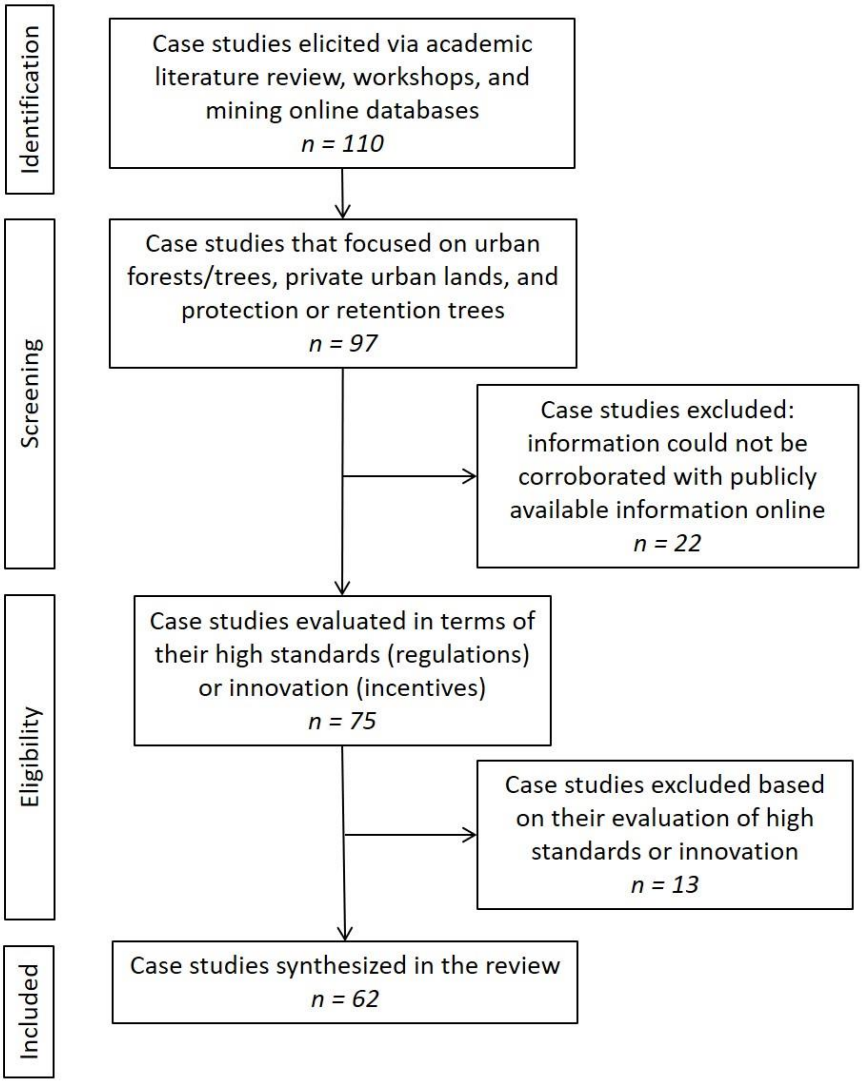

Figure 3: Flowchart showing the results of the case study review

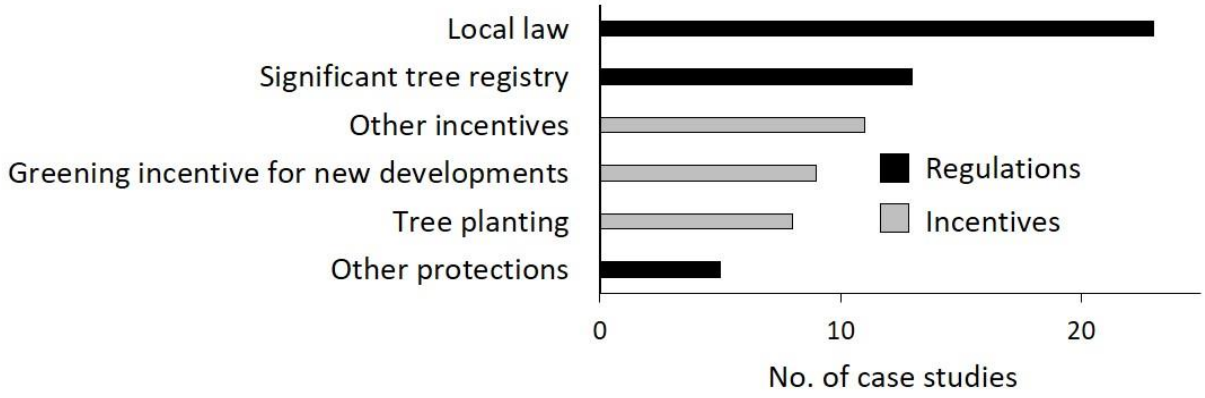

Figure 4: Types of mechanisms included in the case studies reviewed (based on empirical data collected about case studies included in Supplementary Material 4)

421 *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:* * *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
* Bolean operators such as AND OR were used in between groups to include or exclude words in the search		

422

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 & 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 & Loeb, 1990; Dickerson et al., 2001; Schmied & Pillmann, 2003; Conway & 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

454 level, and whether they rent or own the property (Dilley & Wolf, 2013; Avolio et al., 2018).
455 These people are also aware of the perceived risks associated with trees, including fire, wind-
456 throw and infrastructure damage (Kirkpatrick et al., 2012). In one study investigating people's
457 attitudes towards regulatory mechanisms that required people to submit permits to remove or
458 alter trees on private urban land (see Conway & Bang, 2014), most respondents did not support
459 the regulation.
460
461 The efficacy of regulatory or incentive mechanisms in terms of how they may influence the
462 number of trees and amount of canopy cover on private land has been difficult to assess. Some
463 studies qualitatively assess the efficacy of regulations at the local level (e.g., Coughlin et al.,
464 1988; Watson, 2015), but do not attach hard data to changes in tree number and canopy cover
465 (Table 4). A more empirical approach involved assessing changes in tree numbers and/or canopy
466 cover over two periods of time, before and after a mechanism were implemented, and comparing
467 cities with and without this mechanism. Some studies using this approach have noted an increase
468 or stabilisation of canopy cover in cities with tree regulations (Sung, 2012), wile others have
469 observed that changes could be as much an effect of internal variations in the regulations than
470 their actual efficacy (Conway & Urbani, 2007). This is because some tree regulations may be
471 enshrined in planning schemes, while others may be simple guidelines, or because some cities
472 may have a stronger enforcement capacity than others (Landry & Pu, 2010). Assessing the
473 efficacy of tree protection mechanisms is complex and influenced by many institutional,
474 economic, and other external and context-specific factors.
475

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

Research Domain	*Research Theme*	*Study ID**
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
* For study ID, see Supplementary Material 1		

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479

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 Figure 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', Figure 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'; Figure 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 (Figure 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

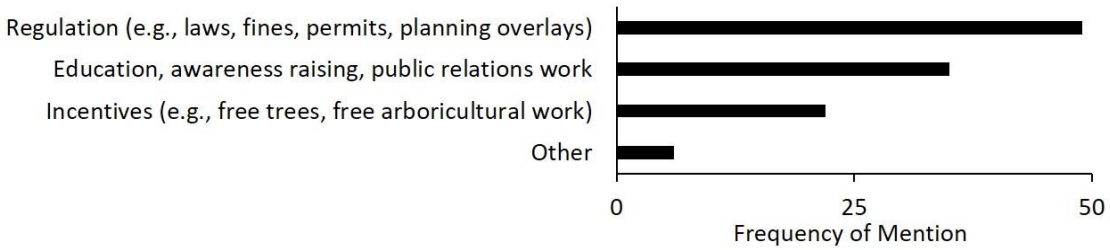
Most reviewed case studies referred to regulation that prevented the removal of trees on private urban land, or financial incentives that encouraged the retention or planting of trees in new or re-developed sites (see details in Supplementary Material 4). The four most innovative cases are described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

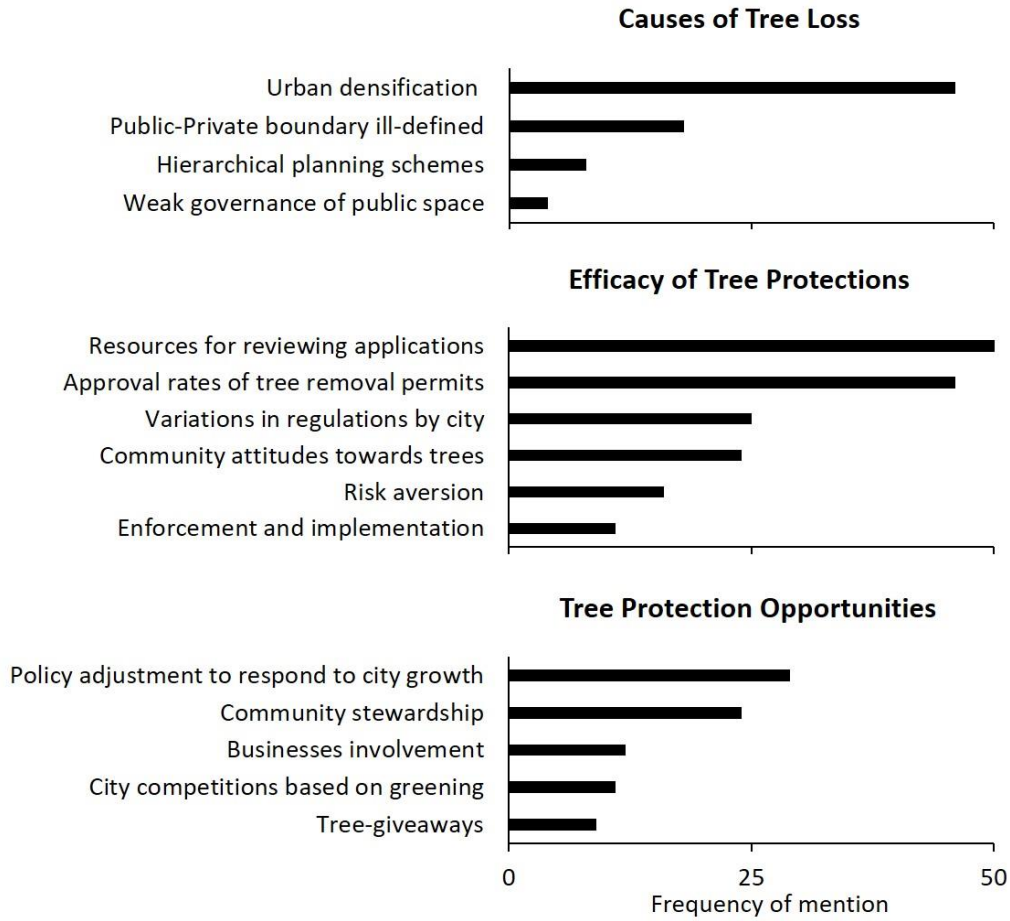
5. The City of Stonnington in metropolitan Melbourne is implementing tree bonds on private land as a mechanism for protection. Tree bonds are used by many Australian cities, including Bendigo, Stirling, and Sydney (Supplementary Material 3), but only Stonnington applies them to private urban land (City 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.



542

543 *Figure 5:* The frequency of types of mechanisms for protecting or retaining trees on private
544 urban land as mentioned by urban forest managers working in Victoria, Australia

545



546

547 *Figure 6:* The frequency of themes related to causes of tree loss, efficacy of tree protection, and
548 tree protection opportunities on private urban land based on the social data collected from
549 international urban forest professionals

550

5.1.1 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).

5.1.2 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 $3,000 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.

6. 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 & Duinker, 2013; Plant et al., 2017; FAO, 2018; TNC, 2019; Nowak & 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 & 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.

6.1 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 & 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 & 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 & 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

644 between local governments, or before and after a single local government established and applied
645 a tree protection regulation. Ultimately, to improve this research we must find a way to decouple
646 the specific type of mechanism being used from the ability of local governments to implement it
647 (Conway & Urbani, 2007; Landry & Pu, 2010), as well as develop a clearer, more objective, or
648 at least a more comparable subjective definition of what efficacy means, and perhaps more
649 importantly, a framework as to how efficacy can be better evaluated (see Table 5).
650
651 Incentive mechanisms may be more desirable for many local governments because they reduce
652 bureaucracy, often require less resource support, and do not promote an image of an overly
653 intrusive government based on strict regulation. Promoting the preferred behavior can lead to
654 less resistance than enforcing mandatory requirements. However, while academics have argued
655 for decades for more incentives (e.g., Coughlin et al., 1988; Watson, 2015; Brown et al., 2018;
656 FAO, 2018; Juhola, 2018; Clark et al., 2020), there is little evidence of their development, use or
657 efficacy. Many local strategic documents on urban forests mention the importance of some of
658 these incentives (e.g., tree awareness campaigns, adopt-a-tree programs for private homeowners;
659 see Young, 2011; Ordóñez & Duinker, 2013), which aim to increase tree retention on private
660 urban land. However, these lack the detail on how they are developed, operated, and monitored
661 for their effectiveness. There is no information or monitoring as to whether they result in greater
662 tree retention or canopy cover. Consequently, most research on incentives remains anecdotal.
663 Our study has attempted to advance beyond this anecdotal evidence and evaluate incentive
664 mechanisms for their innovation.
665
666 We believe innovative incentive mechanisms can help establish a paradigm shift for local
667 governments, by reinforcing the value of trees and the responsibility of private landowners and
668 other private stakeholders to take care of their trees, thus promoting community stewardship
669 (Young, 2011; Boulton et al., 2018; Brown et al., 2018; Bush & Hes 2018). Our social science
670 studies have shown that many urban forest professionals are already aware of the value of these
671 mechanisms. For incentives to be effective, local governments should establish regulations that
672 support them, avoid regulatory contradictions, and establish long term monitoring programs
673 based on baselines (Juhola, 2018). These baselines may include locally-based tree valuations
674 (e.g., Doick et al., 2018) or codifying the vegetation types to be retained (e.g., City of

675 Washington DC, 2019). Incentives may also involve supporting citizen-led activities focused on
676 planting or protecting trees on private land, and awarding prizes for volunteer activities (Young,
677 2011; Watson, 2015; Daniel et al., 2016; Bush & Hes 2018; Buijs et al., 2019).
678
679 Finally, even in cases where innovative mechanisms are implemented, cities may still experience
680 urban forest loss and removal. This is because of the impact of urban development (e.g., Hurley
681 et al., 2019; Nowak & Greenfield, 2020), the reduced performance of trees due to the
682 challenging and constantly changing growing conditions (Vogt et al., 2015), and, just as
683 important, their senescence. Therefore, replacement strategies are as important in protecting and
684 retaining urban trees as implementing regulatory and incentive mechanisms. Without plans to
685 replace trees, the space previously occupied by a large tree may provide new land for urban
686 development, and this can further undermine our capacity to protect the urban forest. The soil,
687 root system, and canopy of the space must also be accounted for.
688
689 **6.2 The Role of Community**

690 Protecting and retaining trees on private urban land is not just a technical issue to be solved by
691 local governments. There is also a need for understanding broader community issues, including
692 people's perceptions of urban trees and regulations/incetives, community engagement, as well as
693 community stewardship and behaviour change.
694
695 To engage the community and promote stewardship, we must first understand the public's
696 perception of urban trees, and this includes trees not just on a landowner's property but also trees
697 on other people's private land. This has not yet been investigated. Empirical research in this area
698 has shown that most people have a positive attitude towards street trees (Schroeder et al., 2006)
699 and a negative attitude towards existing regulations that require people to apply for a permit to
700 remove a tree (Conway & Bang; 2014; Conway & Lue, 2018). However, these attitudes vary by
701 context (e.g, private vs. public trees) and demographics (e.g., homeowner vs. tenant; see Dilley
702 & Wolf, 2013; Conway & Bang; 2014; Avolio et al., 2018). This is because social perceptions of
703 trees are not monolithic and are expressed in various ways, from variable and less stable attitudes
704 and preferences, to deeply held and more stable beliefs and values (Pearce et al., 2015). In other
705 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 & 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 & Duinker, 2013; Brown et al., 2018) to tree-planting campaigns (Carmichael & 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 & 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.

6.3 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 recognise 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 recognise 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 & 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.

751 *Table 5:* Principles and criteria for evaluating and monitoring the usefulness and innovativeness
752 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.

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Supplementary Material

Supplementary Material 1 – *List of articles based on systematic literature review*

Studies included in literature review (n=43). Numbers refer to Study ID in Table 4, main text.

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Supplementary Material 2 – *Details of Types of Mechanisms used in Victorian Local Governments*

Questions in the online survey relevant to this research study:

Question No.	*Field*	*Question (Verbatim)*	*Type of measure*	*Measure*
1	City work [a]	Do you work for a city council or local government authority (LGA)?	Categorical, discrete	Yes, No, Prefer not to answer
2	Field	What professional field do you identify with?	Categorical, multiple choice	Horticulture/arboriculture, urban forests, urban planning, forestry, urban ecology, landscape architecture, community planning, open space and recreation planning, Other [Define]
3	Local government type [b]	How would you classify your LGA or city council?	Categorical, discrete	Inner, Middle, Outer, Regional, Other [Define]
4	Trees on private lands	How does your LGA encourage the protection, retention, or planting of trees on private lands?	Categorical, multiple choice	Education, awareness raising, public relations work / Incentives (e.g., free trees, free arboricultural work) / Regulation (e.g., laws, fines, permits, planning overlays) / Other 1 [Define] / Other 2 [Define] / Other 3 [Define]

[a] Conditional question: answering yes meant progressing through survey

[b] Based on VPA (2018) classifications; "inner", "middle", and "outer" refer to their distance from the central local government in Greater Melbourne (i.e., City of Melbourne); "regional" refers to councils outside the Greater Melbourne area in Victoria, Australia. No responses were obtained for "Other" option.

Characteristics of the respondents of the online survey (n=61):

Characteristic	*Categories*	*Number of cases*	*% of total responses* [a]
Local government type where respondent worked [b]	*Inner council*	28	46
	Middle council	10	16
	Outer council	13	21
	Regional council	8	13
Professional field [c]	*Horticulture / Arboriculture / Urban Foresry*	68	57
	Other	51	43

[a] N=61; percentages may not add to 100% due to rounding

[b] Based on VPA (2018) classifications; "inner", "middle", and "outer" refer to their distance from the central local government in Greater Melbourne (i.e., City of Melbourne); "regional" refers to councils outside the Greater Melbourne area in Victoria, Australia

[c] Multiple choice, unrestricted answer. Options "Horticulture/Arboriculture"and "Ubran Forestry" were originally separated and then aggregated. Option "Other" includes "Ecology (forest or wildlife ecology, etc.)", "Urban planning", "Architecture (including Landscape Architecture)", "Community Planning", "Open Space / Recreation Planning", and "Other (open answer)"

Supplementary Material 3 –*Details on International Workshops*

Workshop questions:

1. We are interested in how and why cities retain and protect trees on private land. This can include regulations, such as financial penalties for removing trees, or incentives, such as tax rebates for retaining existing trees. What are your experiences with these mechanisms, and what is their efficacy?

2. What do you think are the motivations for local governments to pay attention to this issue? Are there any concerns about trees on private urban land?

3. What is it about trees that influences the decisions of cities to protect or retain them?

4. We are interested in who influences local governments in the way they protect trees on private land. What types of people, organizations, or institutions, influence these decisions?

5. What tools, such as land management agreements or financial agreements, are available to local governments to engage with the private land-owning community, such as commercial or industrial landowners, house-owning residents, and private conservation organizations?

Demographic profile of workshop participants (n=25):

Characteristic	*Categories*	*Number of cases **
Type of organization where participants worked	Academic	10
	Business, consultancy	5
	Local government	9
	National or regional government	2
	Non-Government Organization (NGO)	3
Countries where participants worked	Belgium	1
	Brazil	1
	Canada	2
	Colombia	1
	France	4
	Germany	1
	India	2
	Malaysia	1
	Netherlands	1
	Switzerland	1
	United Kingdom	6
	United States	5
Gender	Female	13
	Male	12
* May not add up to 25 due to overlap		

123 *Selected inductive coding examples, indicating assigned code(s) and themes*

Example	*Verbatim data*	*Assigned code(s)**	*Themes **	*Reference*
1	"In some countries it's about balancing land value and space, and the land has a high value n some places. In [name of country], there have been new landscaping and tree requirements, but most people apply things on a case-by-case basis"	Urban densification Variations in regulations by city Enforcement and implementation	Causes of tree loss Efficacy of tree protections	May_PE1
2	"I live in one of the less forested areas in Europe. And yeah, you would say we need public awareness, because most people don't think of trees, but then most of the vegetation is in private lands. Gardens in [name of city] account for 8% cover of the area of the city! There is a lot of potential, but you also need to think that almost every piece of land is taken in [name of country]."	Urban densification Community attitudes towards trees Community stewardship	Causes of tree loss Efficacy of tree protections Tree protection opportunities	Jun_PW3
3	"The thing is that the housing market is in boom at the moment in cities like [name of cities]. There are big real estate projects, all for increasing density right, and tons of trees are lost there, simply because the city just lets them go. And then the only programs that the city has are plant sales. Which is important, I mean, but you really wonder if that's really effective, right?"	Urban densification Weak governance of public space Tree give-aways	Causes of tree loss Tree protection opportunities	May_PE13
4	"it's not about the trees, right? It's about zoning, building code, and what and where do authorities regulate. The price of land, that's what's driving the conversation, because cities make money from selling land"	Urban densification Weak governance of public space	Causes of tree loss	Jun_PW9
5	"If the people stand up for the trees, then cities will find it less risky, say, less politically expensive, to trigger the protections they have""	Community attitudes towards trees Risk aversion Community stewardship	Efficacy of tree protections Tree protection opportunities	Jun_PW18

Brackets [ ] are used to not disclose private information
* These relate to analysis themes in Figure 5, main text

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Supplementary Material 4 – *List of Case Studies reviewed*

The following is a synthesis of innovative mechanisms to protect and retain trees on private urban land, including the cities where they are used and the source of information (n=62). The mechanisms are classified in the following way:

Types of Mechanisms	*Code*
Local law that protects all or some trees on private land*	LL
Significant, Heritage, or Exceptional tree registries	ST
Greening incentive for new developments	GI
Tree planting programs	TP
Other incentives (see case-study details)	OI
Other protections (see case-study details)	OP

* This also includes planning scheme instruments, such as overlays and/or zonings. This was due to the different and overlapping ways case studies classified these instruments, which made it difficult to differentiate strict local laws from planning zoning and/or overlays.

Note that none of our cases were extracted from the international case study databases initially selected (Table 3, main text). The only mention of "private" in these databases was to describe the public-private partnerships that were established to fund tree planting programs on public land. In our searches we found one existing nation-wide compilation of local tree protection locations in Canada authored by the University of Toronto (see http://forests-settled-urban-landscapes.org/UrbanForestryFootprint/UFmap.html, visited on Oct 2019). However, this database was note useful as it was not explicit about the type of protection that existed.

City	*Country*	*Code*	*Description of innovation or details of mechanism*	*Source*
Adelaide	Australia	LL	Blanket or general law (all trees). Defined by size of tree. Min penalty for private trees: $75; max penalty for public trees: $60,000	Lensink, M. (2012). Tree protection laws in australian states and territories. TreeNet Org, Adelaide, SA, Australia, pp. 15. Retrieved from https://treenet.org/resources/tree-protection-laws-in-australian-states-and-territories/, Oct 2019.
Atlanta	US	LL	Combination of tree ordinances (blanket or general law) and zoning ordinances, smart-growth projects, designation of key management person, existence of tree board.	Hill, E., Dorfman, J.H.; Kramer, E. (2010). Evaluating the impact of government land use policies on tree canopy coverage. Land use Policy 27 (2), 407-414. https://doi.org/10.1016/j.landusepol.2009.05.007 Merry, K., Siry, J., Bettinger, P.; Bowker, J.M. (2014). Urban tree cover change in Detroit and Atlanta, USA, 1951–2010. Cities 41, 123-131. https://doi.org/10.1016/j.cities.2014.06.012

City	*Country*	*Code*	*Description of innovation or details of mechanism*	*Source*
Auckland	New Zealand	ST	Significant tree registry. Protection based on cultural not biodiversity reasons.	Wyse, S.V., Beggs, J.R., Burns, B.R.; Stanley, M.C. (2015). Protecting trees at an individual level provides insufficient safeguard for urban forests. Landscape Urban Plan. 141, 112-122. https://doi.org/10.1016/j.landurbplan.2015.05.006
Austin	US	ST	Heritage tree registry, 33,000 trees, 95% of all heritage trees adequately protected	Mars, K. (2014) Heritage tree report. Austin, TX, USA. Retrieved from http://www.austintexas.gov/edims/document.cfm?id=227900, Oct 2019
		TP	Tree planting program on private and public urban land to obtain carbon credits for the city to meet carbon goals.	City of Austin (2017) State of our Environment Report. Austin, TX, USA. Retrieved from https://data.austintexas.gov/stories/s/2017-State-of-Our-Environment-Report-Urban-Forest-/mquz-kyrj/, Oct 2019. Lavy, B.L.; Hagelman III, R.R. (2017). Spatial and temporal patterns associated with permitted tree removal in austin, texas, 2002–2011. The Professional Geographer 69 (4), 539-552. https://doi.org/10.1080/00330124.2016.1266953
Baltimore	US	TP	Tree-planting programs on private land	Nguyen, V.D., Roman, L.A., Locke, D.H., Mincey, S., Sanders, J.R., Fichman, E.S., Duran-Mitchell, M.; Tobing, S.L. (2017). Branching out to residential lands: Missions and strategies of five tree distribution programs in the U.S. Urban Forestry & Urban Greening 22, 24-35. https://doi.org/10.1016/j.ufug.2017.01.007
Banyule	Australia	ST	Significant tree registry. Protected by combined local law and Vegetation Protection Overlay (VPO). Alteration/removal requires planning permit	City of Banyule (2017). Significant Trees. Banyule, VIC, Australia. Retrieved from https://www.banyule.vic.gov.au/Waste-environment/Environment-sustainability/Significant-trees, Oct 2019
Bayside	Australia	LL	Blanket or general law (all trees). Specifies private trees	City of Bayside (2012). Consolidated local Law No. 2 - Neighbourhood Amenity. Bayside, VIC, Australia. Retrieved from https://www.bayside.vic.gov.au/sites/default/files/bcc_local_laws_no_2_neighbourhood_amenity_2015.pdf, Oct 2019
Bendigo	Australia	OP	Tree bonds	City of Bendigo (2017) Urban Tree Management Policy .Retrieved from https://www.bendigo.vic.gov.au/About/Document-Library/urban-tree-management-policy, Oct 2019

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City	*Country*	*Code*	*Description of innovation or details of mechanism*	*Source*
Boone	US	OI	Tax credits defined by size of tree to preserve trees in local properties	Bardon, R.; King, B. (2019). Protecting and retaining trees - A guide for municipalities and counties in north Carolina. North Carolina State University, Raleigh, NC, US. Retrieved from https://content.ces.ncsu.edu/protecting-and-retaining-trees-a-guide-for-municipalities-and-counties-in-north-carolina, Oct 2019.
Boroondara	Australia	LL	Blanket or general law (all trees). Specifies private trees	City of Borrondara (2016) Tree Protection Local Law. Borrondara, VIC, Australia. Retrieved from https://www.boroondara.vic.gov.au/sites/default/files/2017-05/Tree-Protection-Local-Law.pdf, Oct 2019
Canberra	Australia	LL	Blanket or general law (all trees). Specifies private trees	Australian Capital Territory (2015) Tree Protection act - 2005. ACT, Australia. Retrieved from https://www.legislation.act.gov.au/a/2005-51, Oct 2019.
		ST	Significant tree registry. Protected by combined capital territory planning scheme. Currently facing legal challenges over the validity of tree protection over economic reasons.	Lensink, M. (2012). Tree protection laws in australian states and territories. TreeNet Org, Adelaide, SA, Australia, pp. 15. Retrieved from https://treenet.org/resources/tree-protection-laws-in-australian-states-and-territories/, Oct 2019. Australian Capital Territory (2017) Tree Reistry. ACT, Australia. Retrieved from https://www.tccs.act.gov.au/city-living/trees/act_tree_register, Oct 2019
Hawaii (all cities, state-wide)	US	ST	Significant tree registry. Most trees are exceptional even if there is another landowner.	City of Honolulu (2019) Exceptional Tree Progam. Honolulu, Hawaii, US. Retrieved from http://www.honolulu.gov/parks/hbg/exceptional-tree-program.html, Oct 2019 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
		OI	Tree-retention incentive: tax cut for private residents to maintain their exceptional trees. Maximum of $3,000 per tree per year for maintenance (pruning, mulching, etc.)	Hawaii State Legislature (1975). Act 105. Environmental Quality. Retrieved from https://www.capitol.hawaii.gov/slh/Years/SLH1975/SLH1975_Act105.pdf, May 2020 The Tax Foundation (2006) Exceptional tree deductions. Hawaii, US. Retrieved from https://taxfoundation.org/exceptional-tree-deduction/, Oct 2019 City and County 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, Jan 2020

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City	*Country*	*Code*	*Description of innovation or details of mechanism*	*Source*
Helsinki	Finland	GI	Green factor tool as a greening incentive for new developments	Juhola, S. (2018). Planning for a green city: The green factor tool. Urban Forestry & Urban Greening 34, 254-258. https://doi.org/10.1016/j.ufug.2018.07.019
Indianapolis	US	GI	Tree retention index calculated via water runoff benefits for new developments, based on reduction of impervious surface or volume	Fitzko, D. (2014). Tree credit systems and incentives at the site scale. Urban and Community Forestry, Vermont Dept. of Forests, Parks & Rec. Stone Environmental, Inc., Montpelier, VT, US, pp. 24. Retrieved from https://vtcommunityforestry.org/sites/default/files/pictures/site_scale_tree_credits_2014_02_28_final.pdf, Oct 2019. City of Indianapolis (2009). Stormwater design and specification manual. Indianapolis, IN, US. Retrieved from http://www.indy.gov/eGov/City/DPW/SustainIndy/WaterLand/Documents/Final.pdf, Oct 2019
Kingston	Australia	LL	Blanket or general law (all trees). Specifies private trees.	City of Kingston (2017). Community local law (Consolidated). Kingston, VIC, Australia. Retrieved from https://www.kingston.vic.gov.au/About-Us/Local-Laws-and-Health/Local-Laws, Oct 2019
Lakeway	US	LL	Blanket or general law (all trees). Specifies private trees.	Sung, C.Y. (2012). Evaluating the efficacy of a local tree protection policy using LiDAR remote sensing data. Landscape Urban Plan. 104 (1), 19-25. https://doi.org/10.1016/j.landurbplan.2011.09.009
London	UK	GI	Urban greening factor as an incentive to retain trees via tree valuation. Calculates the potential of greening of a new development area. Existing trees get a higher score than simply grass.	Greater London Authorioty (2017) Green Infrastructure. London, UK. Retrieved from https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/draft-new-london-plan/chapter-8-green-infrastructure-and-natural-environment/policy-g5, Oct 2019 City of London (2018) Urban greening factor study. London, UK. Retrieved from https://www.cityoflondon.gov.uk/services/environment-and-planning/planning/planning-policy/local-plan/Documents/urban-greening-factor-study.pdf, Oct 2019
Los Angeles	US	LL	Blanket or general law (all trees). Specifies private trees. Specifies species (quercus genus, oak trees)	Los Angeles City (2006). Los Angeles Tree ordinance report. Los Angeles, CA, US. Retrieved from https://cityplanning.lacity.org/Code_Studies/Other/ProtectedTreeOrd.pdf, Oct 2019; County of Los Angeles (2011) Urban Forestry Program Manual. Los Angeles, CA, US. Retrieved from http://file.lacounty.gov/SDSInter/dpr/184720_UFPMANUAL080211.pdf, Oct 2019

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City	*Country*	*Code*	*Description of innovation or details of mechanism*	*Source*
Maarondah	Australia	GI	Blanket or general law (all trees). Protected by combined local law and Vegetation Protection Overlay (VPO).	City of Maroondah (2019) Vegetation policy review. Maroondah, VIC, Australia. Retrieved from https://yoursay.maroondah.vic.gov.au/40256/documents/97895, Oct 2019
Malmö	Sweden	OI	Tree-retention incentive for private residents. Swedish building act protects trees and encourages replacement	Juhola, S. (2018). Planning for a green city: The green factor tool. Urban Forestry & Urban Greening 34, 254-258. https://doi.org/10.1016/j.ufug.2018.07.019
Melbourne	Australia	ST	Significant tree registry. Most trees on private land. Protected by combined local law and Environmental Significance Overlay (ESO). Any alteration/removal requires a planning permit	City of Melbourne (2018) Exceptional tree registry. Melbourne, VIC, Australia. Retrieved from https://www.melbourne.vic.gov.au/community/greening-the-city/tree-protection-management/Pages/exceptional-tree-register.aspx, Oct 2019 City of Melbourne (2018) Tree Retention and Removal policy. Melbourne, VIC, Australia. Retrieved from https://www.melbourne.vic.gov.au/community/greening-the-city/tree-protection-management/Pages/tree-protection-policy.aspx, Oct 2019
		OP	Tree replacement standards: advanced tree valuation compensatory formula	
Moonee Valley	Australia	ST	Significant tree registry. Protected by combined local law and Environmental Significance Overlay (ESO). Any alteration/removal requires a planning permit	City of Moonee Valley (2015) Significant Tree Registry Fact Sheet. Moonee Valley, VIC, Australia. Retrieved from https://www.mvcc.vic.gov.au/planning-and-building/long-term-planning-in-moonee-valley/significant-trees.aspx, Oct 2019
Montreal	Canada	LL	Blanket or general law (all trees). Specifies private trees. Application varies across boroughs.	Ville de Montreal (2005) Tree Policy. Montreal, QC, Canada. Retrieved from http://servicesenligne.ville.montreal.qc.ca/sel/publications/PorteAccesTelechargement?lng=En&systemName=7761598&client=Serv_corp, Oct 2019
Moreland	Australia	LL	Blanket or general law (all trees). Specifies private trees.	City of Moreland (2018) Planning Scheme Review Report. Moreland, VIC, Australia. Retrieved from https://www.moreland.vic.gov.au/globalassets/areas/strategic-planning/planning-scheme-review-report-2018---adopted.pdf, Oct 2019. City of Moreland (2018). General Local Law. Moreland, VIC, Australia. Retrieved from https://www.moreland.vic.gov.au/globalassets/areas/local-laws/moreland-city-council-general-local-law-2018.pdf, Oct 2019

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City	*Country*	*Code*	*Description of innovation or details of mechanism*	*Source*
New South Wales (all cities, state-wide)	Australia	LL	Blanket or general law (all trees; Tree Preservation Orders; Local Environment Plans). Defined by size of tree.	Lensink, M. (2012). Tree protection laws in australian states and territories. TreeNet Org, Adelaide, SA, Australia, pp. 15. Retrieved from https://treenet.org/resources/tree-protection-laws-in-australian-states-and-territories/, Oct 2019. Kelly, A.H. (2014). Amenity enhancement and biodiversity conservation in australian suburbia: Moving towards maintaining indigenous plants on private residential land. International Journal of Law in the Built Environment 6 (1/2), 91-105. https://doi.org/10.1108/IJLBE-05-2013-0022 Watson 2015
New York	US	LL	Blanket or general law (all trees; Tree Protection Ordinance)	Cooper, J.C. (1996). Legislation to protect and replace trees on private land: Ordinances in westchester county, new york. Journal of Arboriculture 22 (6), 270-278. Nguyen, V.D., Roman, L.A., Locke, D.H., Mincey, S., Sanders, J.R., Fichman, E.S., Duran-Mitchell, M.; Tobing, S.L. (2017). Branching out to residential lands: Missions and strategies of five tree distribution programs in the U.S. Urban Forestry & Urban Greening 22, 24-35. https://doi.org/10.1016/j.ufug.2017.01.007
		TP	Tree-planting programs on private land	
Ontario (all cities, state-wide)	Canada	ST	Significant tree registry. Protected by combined local law and Provincial-Wide Heritage Tree Registry managed by Forests Ontario, Ontario Heritage Trust, and Urban Forest Council of Ontario.	Ontario Urban Forest Council (2013) Heritage Trees. Retrieved from https://www.oufc.org/heritage-trees/identifying-heritage-trees/; https://www.forestsontario.ca/blog/2013/07/26/trees-ontarios-heritage-tree-program-records-and-celebrates-legacy-tree-landmarks/, Oct 2019
Perth	Australia	LL	Blanket or general law (all trees). Specifies private trees.	Government of Western Australia (2018). Better urban forest planning. Perth, WA, Australia. Retrieved from https://www.clearwatervic.com.au/resource-library/guidelines-and-strategy/better-urban-forest-planning-a-guide-to-support-the-enhancement-of-urban-forests-in-western-australia.php, Oct 2019 Brown, H., Proust, K., Newell, B., Spickett, J., Capon, T.; Bartholomew, L. (2018). Cool Communities—Urban density, trees, and health. International Journal of Environmental Research and Public Health 15 (7), 1547. https://doi-org/10.3390/ijerph15071547

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City	*Country*	*Code*	*Description of innovation or details of mechanism*	*Source*
Philadelphia	US	GI	Tree retention index calculated via water runoff benefits for new developments, based on reduction of impervious surface or volume	City of Philadelphia (2013). Stormwater Management Incentives Program Grant Fact Sheet. Philadelphia, PA, US. Retrieved from http://www.phillywatersheds.org/doc/SMIP_Grant_Factsheet_FY13.pdf, Oct 2019; Fitzko, D. (2014). Tree credit systems and incentives at the site scale. Urban and Community Forestry, Vermont Dept. of Forests, Parks & Rec. Stone Environmental, Inc., Montpelier, VT, US, pp. 24. Retrieved from https://vtcommunityforestry.org/sites/default/files/pictures/site_scale_tree_credits_2014_02_28_final.pdf, Oct 2019. Nguyen, V.D., Roman, L.A., Locke, D.H., Mincey, S., Sanders, J.R., Fichman, E.S., Duran-Mitchell, M.; Tobing, S.L. (2017). Branching out to residential lands: Missions and strategies of five tree distribution programs in the U.S. Urban Forestry & Urban Greening 22, 24-35. https://doi.org/10.1016/j.ufug.2017.01.007 Roman, L.A., Battles, J.J.; McBride, J.R. (2014). Determinants of establishment survival for residential trees in sacramento county, CA. Landscape Urban Plan. 129 22-31. https://doi.org/10.1016/j.landurbplan.2014.05.004
		TP	Tree-planting programs on private land	
		OI	Community stewardship programs "Cool streets" contest.	
Phoenix	US	TP	Tree planting program on private and public urban land to obtain carbon credits for the city to meet carbon goals. Travel miles program for tree planting (incremental, not replacement trees)	CityLab (2018) Article. Retrieved from https://www.citylab.com/environment/2018/08/carbon-offsets-for-urban-trees-are-on-the-horizon/568378/, Oct 2019 FAO (2018). Forests and sustainability cities - inspiring stories from around the world. FAO, UN, Rome, Italy, pp. 92. Retrieved from http://www.fao.org/3/I8838EN/i8838en.pdf, Oct 2019.

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City	*Country*	*Code*	*Description of innovation or details of mechanism*	*Source*
Portland	US	LL	Blanket or general law (all trees). Specifies private trees.	City of Portland (2011) City wide tree policy and review. Portland, OR, US. Retrieved from https://www.portlandoregon.gov/bps/article/331401, Oct 2019
		GI	Tree retention index (TreeBate Program) calculated via water runoff benefits for new developments, based on reduction of impervious surface or volume	City of Portland (2017) TreeBate Program. Portland, OR, US. Retrieved from https://www.portlandoregon.gov/bes/51399, Oct 2019
		OI	Community-based tree monitoring	City of Portland (2017) Tree Program. Portland, OR, US. Retrieved from https://www.portlandoregon.gov/parks/53181, Oct 2019
		OI	Tree giveaways as an incentive to plant trees on private land. Partnership with Friends of the Trees (https://friendsoftrees.org/)	City of Portland (2017) Tree Program. Portland, OR, US. Retrieved from https://www.portlandoregon.gov/trees/60087, Oct 2019
Providence	US	TP	Tree-planting programs on private land	Nguyen, V.D., Roman, L.A., Locke, D.H., Mincey, S., Sanders, J.R., Fichman, E.S., Duran-Mitchell, M.; Tobing, S.L. (2017). Branching out to residential lands: Missions and strategies of five tree distribution programs in the U.S. Urban Forestry & Urban Greening 22, 24-35. https://doi.org/10.1016/j.ufug.2017.01.007
Sacramento	US	LL	Blanket or general law (all trees). Specifies private trees.	City of Sacramento (2016) Tree ordinance. Sacramento, CA, US. Retrieved from https://www.cityofsacramento.org/Public-Works/Maintenance-Services/Trees/Permits-Ordinances, Oct 2019
San Francisco	US	LL	Blanket or general law (all trees). Specifies trees as "significant" (private or next to property) and "landmark" (highest protection, defined by size) trees	City of San Francisco (2008) Tree protection legislation. San Francisco, CA, US. Retrieved from http://sfdbi.org/ftp/uploadedfiles/dbi/Key_Information/TreeProtectionLegislation.pdf, Oct 2019
		ST	Significant tree registry	

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City	*Country*	*Code*	*Description of innovation or details of mechanism*	*Source*
Seattle	US	LL	Blanket or general law (all trees). Specifies private trees. Protected by combined local law and zoning mechanisms and setback standards.	City of Seattle (2007). Urban forest management plan. Seattle Government (SeattleGov), Seattle, WA, USA, pp. 106. Retrieved from www.seattle.gov/trees/management.htm, Oct 2019.
		ST	Significant tree registry. Includes trees on private land	City of Seattle (2018). Tree protection regulation review. Seattle, WA, US. Retrieved from https://www.seattle.gov/Documents/Departments/UrbanForestryCommission/Resources/Final%20Report_Tree%20Regulation%20Research%20ProjectPahseII_31MAR2017_final.pdf, Oct 2019
		GI	Tree retention index calculated via water runoff benefits for new developments, based on reduction of impervious surface or volume	
		GI	Urban Greening Factor formula, calculates the potential of greening of a new development area. Trees get a higher score than simply grass	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.
		OI	Tree-giveaway programs to plant trees on private urban land	City of Seattle (2019) Trees for Neighbourhoods program. Retrieved from https://www.seattle.gov/ trees/planting-and-care/trees-for-neighborhoods Young, R.F. (2011). Planting the Living City Best Practices in Planning Green Infrastructure-Results From Major U.S. Cities. Journal of the American Planning Association 77 (4), 368-381. https://doi.org/10.1080/01944363.2011.616996
South Perth	Australia	LL	Significant tree registry. Uses National Trust criteria	Lensink, M. (2012). Tree protection laws in australian states and territories. TreeNet Org, Adelaide, SA, Australia, pp. 15. Retrieved from https://treenet.org/resources/tree-protection-laws-in-australian-states-and-territories/, Oct 2019.

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Stirling	Australia	LL	Blanket or general law (all trees) to retain existing trees (>4m height) in new developments or plant new tree	City of Stirling (2017) Trees and Development Planning Amendment. Stirling, WA, Australia. Retrieved from https://propertycouncil.com.au/Web/Content/News/WA/2017/City_of_Stirling_introduces_Tress_and_Development_planning_amendment_.aspx, Oct 2019 Western Australian Local Government Association (2019), Policy Advice Document. Retrieved from https://walga.asn.au/getattachment/Policy-Advice-and-Advocacy/Environment/Climate-Change/WALGA-Event-Presentations/Nicole-Mathews-Urban-Forest.pdf.aspx?lang=en-AU, Dec 2019
		OP	Tree bonds	City of Stirling (2019) Trees and Development. Retrieved from https://www.stirling.wa.gov.au/waste-and-environment/trees/trees-and-development, Oct 2019
Stonnington (Council)	Australia	OP	Tree bonds	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
Sydney	Australia	OP	Tree replacement standards: advanced tree valuation compensatory formula	City of Sydney (2017). Tree Valuation formulas. Retrieved from http://peterthyer.com/City%20of%20Sydney%20Tree%20Valuation%20Dec%202003%20%20Peter%20Thyer.pdf, Oct 2019.
Toronto	Canada	LL	Blanket or general law (all trees). Specifies private trees. Anything above 18 inch DBH is protected.	Conway, T.M.; Bang, E. (2014). Willing partners? residential support for municipal urban forestry policies. Urban Forestry & Urban Greening 13 (2), 234-243. https://doi.org/10.1016/j.ufug.2014.02.003 City of Toronto (2018) Private tree bylaw. Toronto, ON, Canada. Retrieved from https://www.toronto.ca/legdocs/municode/1184_813.pdf, Oct 2019. Steenberg, J.W.N., Robinson, P.J.; Millward, A.A. (2018). The influence of building renovation and rental housing on urban trees. Journal of Environmental Planning and Management 61 (3), 553-567.

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Vancouver	Canada	LL	Blanket or general law (all trees). Defined by size of tree. Burnaby and Surrey councils have a tree lawn policy to increase tree numbers in these areas	FAO 2018; City of Vancouver (2018). Urban Forest Strategy - update. Vancouver, BC, Canada. Retrieved from https://vancouver.ca/files/cov/urban-forest-strategy.pdf, Oct 2019
Victoria (state-wide)	Australia	ST	Significant tree registry. Protected by combined local law and state-wide National Trust of Australia's Register of Significant Trees of Victoria	VLRC 2017; National Trust (2017) Significant Tree register. Retrieved from https://www.nationaltrust.org.au/services/significant-tree-register/, Oct 2019
Victoria (state-wide)	Australia	OP	Tree planting standards: Tree replacement and soil deep zone regulations	VLRC 2017; National Trust (2017) Significant Tree register. Retrieved from https://www.nationaltrust.org.au/services/significant-tree-register/, Oct 2019
Western Australia (state-wide)	Australia	OP	Tree planting standards: building codes to include trees, established as areas requirements for tree inclusion, by area	DPLH (2019) Residential building codes. Perth, WA, Australia. Retrieved from https://www.dplh.wa.gov.au/getmedia/5926602c-ab14-46f0-be6f-56dc31c45902/SPP-7-3-R-Codes-Apartments, Oct 2019
Washington	US	GI	Tree retention incentive via the Green Area Ratio calculation, calculated via water runoff benefits for new developments, based on reduction of impervious surface or volume	City of Washington DC (2019). Green Area Ratio. Washington, DC, US. Retrieved from https://doee.dc.gov//sites/default/files/dc/sites/ddoe/page_content/attach, Oct 2019
Whitehorse	Australia	LL	Blanket or general law (all trees. Protected by combined local law and Significant Landscape Overlay (SLO)	Whitehorse City Council (2018). Urban forest strategy. Whitehorse, VIC, Australia. Retrieved from https://www.whitehorse.vic.gov.au/sites/whitehorse.vic.gov.au/files/assets/documents/Urban-Forest-Strategy-2018.pdf, Oct 2019; Whitehorse City Council (2019). Municipal wide tree study. Whitehorse, VIC, Australia. Retrieved from https://www.whitehorse.vic.gov.au/sites/whitehorse.vic.gov.au/files/assets/documents/municipal_wide_tree_study_-_part_2.pdf, Oct 2019

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Whittlesea (Council)	Australia	OP	Tree replacement standards: advanced tree protection standards in the context of development	City of Whittlesea (2016) Tree Protection standards in developments. Retrieved from https://www.planning.vic.gov.au/resource-library/incorporated-documents/whittlesea/wsea-C188-Quarry-Hills-Precinct-Structure-Plan,-June-2016_Part13.pdf, Oct 2019.
Worcester	US	TP	Tree-planting programs on private land	Nguyen, V.D., Roman, L.A., Locke, D.H., Mincey, S., Sanders, J.R., Fichman, E.S., Duran-Mitchell, M.; Tobing, S.L. (2017). Branching out to residential lands: Missions and strategies of five tree distribution programs in the U.S. Urban Forestry & Urban Greening 22, 24-35. https://doi.org/10.1016/j.ufug.2017.01.007

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