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# Protecting trees in the urban forest: a systematic review of literature on acts, bylaws, ordinances, and regulations



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**Manuscript Title:** Protecting trees in the urban forest: a systematic review of literature on acts, bylaws, ordinances, and regulations

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## Abstract

Trees contribute to the livability of cities. To preserve the urban forest, many governments have turned to regulatory mechanisms, ranging from local bylaws and ordinances to state and federal legislation. To understand the history, scope, perspectives, successes, and challenges of disincentive-based tree protection legislation, a systematic review was conducted using PubMD, EBSCOHost, Web of Science, and Scopus. The review, which was not geographically constrained but contained only English-language articles, included 114 publications. The literature highlights that the history of urban forest legislation is long. However, tree protection regulations were popularized more recently, built on years of more general environmental policies. While the adoption processes for tree protection legislation vary across both cities and countries, it is often driven by appreciation of urban forests and led by municipalities with the support of the public and non-governmental organizations. Tree protection legislation defines what trees are to be protected, typically based on size, species, or land use, although cultural or heritage trees are often protected as well. Some tree protection legislation includes replanting clauses and enforcement procedures to increase their effectiveness. The protection of large, culturally important trees and replanting requirements are largely supported by both the public and urban foresters, although support is greater in urban areas. However, whether the legislation actually works is unclear. Conflicting evidence and study limitations preclude direct causal relationships, although areas where tree protection legislation was removed experienced subsequent tree loss. On-going challenges at the local level include underenforcement, conflicting legislation, and underfunded programs. Tree protection legislation is also vulnerable to socio-political changes that prioritize private property rights and development over private tree protection. Amidst widespread urban

tree loss, further research that provides a better understanding of the successes of tree protection legislation will help justify their continued use in urban forestry programs globally.

**Keywords:** jurisprudence, law, legal, rights, rules of the game

## 1. Introduction

The urban population is growing globally, driving land use change and increasing urban density (Broitman and Koomen 2015; Delphin et al. 2016). Urban nature has been shown to increase the livability of these dense spaces, benefiting human health and well-being (Shanahan et al. 2015). Comprising a substantial component of urban nature, trees provide a plethora of benefits to city residents, including air pollution filtration, noise and light pollution reduction, and stormwater regulation (Pataki et al. 2021; Livesley, McPherson, and Calfapietra 2016; Nowak and Dwyer 2007). Yet, for all the benefits trees provide, they are also associated with disservices (Roman et al. 2021). Trees coat cars in pollen, large limbs fall and destroy structures, roots disrupt building foundations, and trees hinder development and construction (Martin and Doucet 2022). These issues contribute to tree removal (Conway 2016). However, because trees are understood as net assets to urban areas, some argue they should be legally protected from indiscriminate removal (Simson 2022). Understanding the socio-legal processes that influence the governance and regulation of the urban forest is important for ensuring the robust protection of trees (Wirtz et al. 2021). This is particularly important amidst the climate crisis (Yang 2009), an increasing prevalence of invasive pests and diseases (Tubby and Webber 2010), and the loss of trees to housing and infrastructure development (Nowak and Greenfield 2012), all of which drive canopy cover loss in the urban environment.

To abate tree loss and grow their urban forests, many municipalities have implemented both incentive and disincentive initiatives. Incentives encouraging urban greening include free tree giveaways (Nguyen et al. 2017), tax breaks for properties with trees (Ordóñez-Barona et al. 2021; Clark, Ordóñez, and Livesley 2020), cost-sharing maintenance (Clark, Ordóñez, and Livesley 2020), and greening incentives to retain trees during development (Ordóñez-Barona et al. 2021).

While incentives encourage community involvement in urban forest management, their effectiveness is limited as their participation is usually voluntary and they seldom abate tree removal. Disincentives typically provide legal protection to trees, regulating who can prune and remove trees and when, punishing non-compliance with fines or imprisonment (Lavy and Hagelman 2019). Such legislation, including bylaws, ordinances, and national acts, has the potential to reduce tree loss and mitigate the impacts of urban development on the urban forest (Hilbert et al. 2019). Disincentive programs also provide more certainty surrounding future change in urban forest structure than incentive programs, which is key in helping cities achieve their urban forestry goals (Wirtz et al. 2021).

Enacted by legislatures, tree protection legislation regulates, prohibits, sanctions, or restricts certain activities related to tree management. The legislation can take the form of state or federal acts or municipal bylaws and ordinances; however, municipal bylaws or ordinances are the most common method for governing urban forests. The terms bylaw and ordinance are largely synonymous and legally equivalent. In the United States of America (USA), tree protection ordinance (TPO) is the common legal term, while bylaws (or by-laws, byelaws, bye-laws) are used elsewhere, including Canada and the United Kingdom. We thus use these two terms interchangeably.



Tree protection legislation has increased over the past century, supported by professional associations, government bodies, and non-governmental organizations. However, a comprehensive literature review has not been conducted to determine the state of knowledge and remaining research gaps surrounding such legislation. While Ordóñez-Barona et al. (2021) conducted a review of urban forest protection and retention mechanisms on private land (Ordóñez-Barona et al. 2021), its scope did not allow for an in-depth discussion of the factors that lead to the development and success of tree protection legislation. This review paper fills these gaps by synthesizing and critically analyzing global research on tree protection legislation in urban areas. We examine how legislation is influenced by social systems, including legal, political, and equity considerations, and drives environmental outcomes, including change in canopy cover. This review will benefit governmental and non-governmental organizations involved in urban forestry legislation by detailing the breadth of current legislative literature.

## 2. Approach

### 2.1 Systematic Review

A systematic literature review was conducted to examine disincentive urban forest legislation related to tree preservation, removal, and replanting. This systematic approach limits the omittance of relevant studies and reduces biases in literature selection (Aromataris and Pearson 2014), following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al. 2021). The search was performed across four databases in February 2024 using *a priori* urban forestry and regulatory mechanism keywords. The urban forestry keywords were “arboriculture”, “canopy cover”, “street tree”, “tree protection”, and “urban forest”. The regulatory mechanism keywords were “act”, “by(e)law”, “by(e)-law”, “legislation”, and “ordinance”. The search was conducted by publication title, keywords, and abstract. The search was not constrained by region nor publication date. Duplicates and non-English papers were manually removed based on the article titles. Neither filters nor automation tools were used to assess eligibility. The summary of the records identified, removed, and excluded is included in the Supplementary Material.

After 363 duplicate records and 284 non-English articles were removed, 1407 records were assessed for eligibility by the first and second authors. Papers were included if they discussed or examined any of the five tree protection legislation themes. Studies were also excluded if only the abstract was available. Twenty-two additional articles and primary sources, including grey literature, were extracted from literature cited in or citing those identified in the search. The 114 included studies were classified by theme and geographical region. An adapted PRISMA framework is provided in the Supplementary Materials.

### 2.2 Research Themes

Thematic analysis per Braun and Clarke (2006) (Braun and Clarke 2006) was used to assign the articles to five inductively coded themes: the (1) history, (2) development, (3) scope, purview, or specifications, (4) perspectives of urban foresters, private industry, and residents, and (5) successes and challenges associated with tree protection legislation. The analysis allowed us to examine the relative level of attention topics have received within the scholarly literature and synthesis research addressing the same theme. To perform the thematic analysis, a preliminary readthrough of the articles was performed to construct preliminary and comprehensive codes. These codes were used to categorize the articles into the themes. Because of the lack of prior systematic analysis, the codes were developed iteratively as opposed to using predetermined codes or themes.

## 3. Findings

The number of articles published annually on tree protection legislation has been steadily increasing over the past 40 years. A graph of the number of articles per year is provided in the

Supplementary Materials. Most articles have been published since 2010 (n = 71, 62.28%), and very few (n = 3, 2.63%) were published before 1990. This is likely related to the rapid increase in the adoption of urban tree protection legislation in the 1980s and 1990s.

Legislative history was the most commonly discussed theme (n = 32, 28.1%), followed by development (n = 31, 27.2%), scope (n = 30, 26.3%), and challenges (n = 30, 26.3%). Perceptions (n = 21, 18.4%) and successes (n = 20, 17.5%) were less frequently considered in the literature. Some studies included multiple themes. Geographically, the USA was heavily represented in the literature (n = 47, 45.19%), followed by Canada (n = 12, 11.54%), England (n = 7, 6.73%), and Australia (n = 6, 5.77%). There was minimal representation of South American and African countries with each continent only having one publication each on Brazil and South Africa, respectively. There was moderate representation from Asia, with nine publications from five countries.



## 3.1 History

### *3.1.1 Preceding Legislation*

Twenty-five papers discussed how existing legislation has led to the development of tree protection bylaws. Most urban tree protection legislation is facilitated or preceded by broader environmental legislation. Two studies described that in European cities, preceding legislation concerned general environmental protection and is enacted at the national level (Sanesi et al. 2017; Profous and Rowntree 1993). For example, the Town and Country Planning Acts, enacted in countries historically under British influence such as Scotland and Malaysia, provided frameworks for environmental conservation during local planning (Akmar et al. 2011; van der Jagt and Lawrence

2019). Tree protection legislation has also been preceded by forestry management or conservation legislation, again often at the national level (Coughlin, Mendes, and Strong 1988; Park and Youn 2013; Kraukle, Stokmane, and Vugule 2022; Atmiş 2016; Lazdinis 2009; Suchocka and Krynicki 2016; Jim and Liu 2000). Sometimes, these preceding national forest or conservation acts mentioned urban forests, such as Poland's *Act on Forest*, Turkey's *Forestry Law*, or Korea's *Forest Resource Act*. While the Polish act incorporated urban forestry into the social function of traditional forestry (Jaszczak, Wazynski, and Wajchman-Switalska 2017; Jaszczak and Wajchman 2015), the Turkish and Korean acts provided both a definition and scope for urban forestry (Atmiş 2016). These national acts, however, did not include specific regulations for urban forests (Jaszczak, Wazynski, and Wajchman-Switalska 2017; Atmiş 2016).

Legislation specific to urban tree protection has often also been preceded by urban forest or greenspace legislation that is focused more generally on the management or planting of trees (Satean 2019; McPherson and Nina 1998; Profous and Rowntree 1993; Zhang et al. 2009). In the Netherlands, for example, as early as 1397 there were regulations regarding where and what species of trees could be planted (Woudstra 2022). In some cases, these laws facilitated urban tree protection legislation, leading to a rapid increase in their development. For example, as a result of the 1990 amendment of the USA's *Farm Bill* to include mentions of urban forestry, 24 states developed urban forest programs (Ries, Reed, and Kresse 2007).

The evolution of urban forestry more generally, which has come to include legal mechanisms for tree protection, has also differed by region. In North America, urban forestry developed under democratic systems with legislative backing (Konijnendijk et al. 2006). Comparatively, European urban forestry largely developed under feudal systems, co-evolving with the broader political and legal background of European countries (Konijnendijk 1997).

In many regions, national- or sub-national-level (e.g., provincial, state) legislation was enacted to give municipalities authority over and responsibility for urban forests (Coughlin, Mendes, and Strong 1988; Park and Youn 2013; Ricard and Bloniarz 2006; Profous and Rowntree 1993; Dunster 1994; van der Jagt and Lawrence 2019; Konijnendijk et al. 2006; Merullo 2007; Woudstra 2022; Andresen 1976; Wood 2004). For example, in Massachusetts, USA, a state law was enacted in 1896 that enabled municipalities to appoint tree wardens, which were the first state-mandated urban forestry professionals in the USA, with several other states following suit shortly thereafter (Ricard and Bloniarz 2006). Similarly, in Ontario, Canada, the *Ontario Municipal Act* enabled municipalities to create and enforce tree protection bylaws, although only large municipalities adopted them at first (Andresen 1976). In other countries, national acts were more stringent: Korea's *Act on Urban Parks and Green Spaces* and Scotland's *Town and Country Planning Act* required local authorities to create management plans or protection ordinances for their urban forests (Park and Youn 2013; van der Jagt and Lawrence 2019).



#### *3.1.2 Timelines*

The historical enactment dates of urban tree protection legislation vary by region and were often driven by local catalysts. Commonly, legislation to protect public trees was introduced before protection for private trees. Across Europe, rapid development of urban tree protection legislation occurred between 1974 and 1985 (Schmied and Pillmann 2003). While bylaws for tree protection similar to those existing today have existed since at least 1930 (Schmied and Pillmann 2003), other tree protection legislation dates back further. For example, during the Bloody Code era – an English legal system from the 18th to 19th centuries – the death penalty was mandated for felling another's tree (Randa 1997). In the USA, a somewhat similar trend occurred. A rapid introduction of tree protection legislation began in the 1980s, but some cities had legislation since the 1920s (Coughlin, Mendes, and Strong 1988). In the USA, this introduction has been tied to economic development and the associated migration to urban areas (Zhang et al. 2009). In South Africa, urban tree protection has also been observed since the 1930s, when certain native species were protected, with non-native species included in protection legislation beginning in 1977 (Bouwer and Gaum Wilma 2000).

Larger-scale historical events, specifically those that resulted in urban tree destruction, have also been identified as contributing to the development of tree protection and urban forest legislation. Following deforestation during the Livonian War, landholders in Tallinn (Estonia) were required to replant trees in and around towns (Sander and Meikar 2003). Following the destruction of urban and community forests during the Korean War, the Office of the Economic Coordinator of South Korea imposed national restrictions and enforcements on tree cutting (Park and Youn 2013; Martin 2023). During and following World War II, the USA supported local ordinances to protect trees in Victory Gardens through collaborative efforts (Miller 2003). In post-war Germany, there was a desire to rebuild the forests that were lost, and regulations were introduced that prevented the felling or pruning of surviving trees (Stilgenbauer and McBride 2010). However, a lack of a national approach resulted in varying re-development efforts (Stilgenbauer and McBride 2010).

## 3.2 Development

### *3.2.1 Drivers of Implementation*

The rationales and drivers of tree protection legislation identified in the literature are diverse, often connected to ecosystem services, politics, nostalgia, conflict mitigation, and advocacy or lobbying. Often, legislative development is driven by public recognition of the importance of urban forest ecosystem services (Zhang et al. 2009; Dickerson, Groninger, and Mangun 2001; Schmied and Pillmann 2003) with environmental benefits most prominent in many ordinances (Lavy and Hagelman 2019). It has also been observed in Turkish municipalities that having an urban forest is considered a political advantage, providing an incentive for them to be managed and protected (Atmiş 2016). In places that have experienced destruction or loss of their urban forests, urban forest protection and development can be driven by nostalgia, leading to the adoption of legislation to create urban forests that mimic what existed previously in size or species composition (Stilgenbauer and McBride 2010; Dunster 1994). Urban tree legislation, including those aimed at tree protection, is also developed to mitigate conflicts between people as much as it is to preserve trees (Zhang et al. 2009). Governance structures and those responsible for urban forests can also drive if and how urban forest protection is mandated (Stilgenbauer and McBride 2010). For example, in New England, tree wardens, motivated primarily by public safety, are responsible for urban forest management, but place little importance on ordinances (Ricard and Bloniarz 2006). However, pressures placed on politicians by the public and advocacy groups have been drivers of the enactment of tree protection bylaws in Canada and the USA (O'Herrin and Shields 2016; Dunster 1994; W. Elmendorf 1993).

International factors have also been found to sometimes drive urban tree protection legislation. In countries such as South Korea and Latvia, as well as in Europe more generally, global discourse on sustainable development and ecological awareness influenced the adoption of urban forest legislation (Park and Youn 2013; Schmied and Pillmann 2003; Kraukle, Stokmane, and Vugule 2022). Many regions rely on these global discourses and precedents to form their own urban forest legislation. For example, South African legislation draws from Western countries (Bouwer and Gaum Wilma 2000) and Malaysian legislation from Britain (Akmar et al. 2011). Thus, there are similarities internationally in urban forest legislation, including tree protection regulations.

While many articles have discussed the scope of existing tree protection legislation, it is also worth noting that several mentioned the lack of mandated tree protection in certain regions. For example, there is no specific urban forest protection legislation in Milan (Sanesi et al. 2017), Latvia (Kraukle, Stokmane, and Vugule 2022), or Lithuania (Lazdinis 2009), though it is sometimes addressed in broader forestry regulations. In Nepal, the lack of protection legislation is attributed to community views, where people see urban forests as something that has aesthetic value, but not something that is essential (Gurung et al. 2012). While urban tree protection legislation exists in Malaysia, they are scarce, often because of the time and resources taken for their development (Akmar et al. 2011).

### *3.2.2 Legislation Development Process*

In addition to drawing inspiration from elsewhere, the literature highlights the development of tree protection legislation often includes key components of policy development such as community engagement. Community engagement is common internationally, involving the public, non-governmental organizations, utilities, and construction companies in the development of tree protection legislation (Zhang et al. 2009; van der Jagt and Lawrence 2019; Elton et al. 2022). In some countries, public participation is even a legal requirement (Papastavrou 2019). However, there were also warnings that urban foresters and consultants should be careful not to let dominant voices preclude the participation of minority groups (Nesbitt et al. 2018; Rishbeth 2001). Despite the emphasis on community engagement, it is not uncommon for this process to be rushed, excluding many steps. In a hurried attempt to introduce legislation, regions may apply frameworks or principles from other levels of policy (Akmar et al. 2011) or copy existing ordinances in other municipalities, changing very few of the details (Dickerson, Groninger, and Mangun 2001).

During the development of tree protection legislation, several factors have been identified as important for ensuring successful implementation. Community engagement and public approval are imperative to their effectiveness, particularly when they contain voluntary regulations or are difficult to monitor and enforce (Zhang et al. 2009; Butt et al. 2021; Wirtz et al. 2021). Garnering public and political support is a necessity in the successful development of strong legislation (Wirtz et al. 2021). It is also important to ensure sufficient financial resources, sufficient staff, and administrative support to oversee enforcement and engage citizens and non-governmental organizations (Zhang et al. 2009; Akmar et al. 2011).

The level of government with responsibility for urban forest management and legislation varies by region and has changed over time. In some countries, such as Czechoslovakia and the USA, responsibility for urban forests is shared between municipal and national or sub-national (e.g., state) governments (Profous and Rowntree 1993; Ries, Reed, and Kresse 2007), whereas other regions have only one responsible government body. For example, Canadian municipalities are solely responsible (Conway and Lue 2018) while in South Korea, tree protection legislation is the responsibility of the national government (Park and Youn 2013). While the lack of local-level involvement in urban forest policy may be common practice in some regions, this can have negative implications on its effectiveness due to a lack of city-specific considerations (Park and Youn 2013). It is also worth noting that the level of government responsible for urban forest legislation can evolve. In the USA, for example, there was a shift in the 1980s from urban tree protection legislation being primarily a local phenomenon to one that had state directives and funding (Coughlin, Mendes, and Strong 1988).

#### *3.2.3 Interactions with Other Legislations*

Several studies highlighted how urban tree protection legislation is often tied to or interacts with other forms of environmental legislation. In some cities in South Africa and the USA, tree protection legislation tends to be specified within broader urban greening or landscape laws. This is the case in Alabama because urban forests are considered part of a landscape that is used for both public and private benefit (Zhang et al. 2009). In Sacramento, tree planting and preservation are addressed within parking lot ordinances that require a certain amount of parking lot shade (McPherson 2001). In other cases, such as South Africa, it is national environmental laws that contain provisions for urban nature, including street trees (Bouwer and Gaum Wilma 2000). Sometimes, urban tree protection is encompassed in multiple different types of legislation at the same time, for example, a specific protection bylaw, but also in building requirement policies, as is often the case in Europe (Schmied and Pillmann 2003). Many cities also have regulations regarding urban forest management beyond tree protection. For example, in Australia, a combination of different policies and acts together govern urban forestry in Canberra and Brisbane (Daniel, Morrison, and Phinn 2016; Lynch 2022). However, one study noted that in the USA, a municipality typically had either a regulation for tree protection or a tree planting program, but not both, though it was not a recent study (Coughlin, Mendes, and Strong 1988).

#### *3.2.4 Amendments*

After the development and implementation of tree protection legislation, they are often amended for a variety of reasons. Sometimes amendments are to update the type of trees protected. For example, in Dresden, Germany, the legislation that stipulated the protection of all trees was amended to protect those only above a certain size (Stilgenbauer and McBride 2010). South Africa amended its tree protection legislation in 1977 to include non-native species (Bouwer and Gaum Wilma 2000). Canberra, Australia, as of 2022, was amending its urban forest legislation to focus on tree protection and conservation issues (Coughlin, Mendes, and Strong 1988). Tree protection legislation also evolves as cities do, resulting in amendments. In many American cities, TPOs evolve in response to changing legal frameworks or as new issues and challenges arise (Zhang et al. 2009). However, at other times amendments are more foundational and are required due to missteps during the original development of the legislation. When communities base their ordinances on those in other cities without regard for local objectives, resources, and socio-political differences, the ordinance may ultimately require amendments to better reflect the sociopolitical and environmental contexts of the community, an often timely and costly undertaking (Dickerson, Groninger, and Mangun 2001). A lack of technical understanding by the public and political figures regarding the types of trees that should be protected also results in amendments as future implications of these decisions, often related to public safety, are not considered (Dunster 1994).

## 3.3 Scope

Urban tree protection legislation can encompass several requirements relating to tree planting, pruning and maintenance of existing trees, heritage tree preservation, hazardous tree removal, or prohibiting digging or removal of trees without a permit (Salisbury et al. 2022; Satean 2019; O'Herrin and Shields 2016); several studies have considered these requirements. Typically, urban tree protection legislation focuses on preventing tree removal. Most legislation is also concerned with individual trees, although there are cases where it applies to groups of trees or land clearing (Coughlin, Mendes, and Strong 1988; Donis 2003; Nicholson 1995; Galvin, Wilson, and Honeczy 2000).

### *3.3.1 Stipulations for Tree Protection*

Most tree protection bylaws designate tree protection by size or species, but those sizes or species vary across cities. When it comes to stipulating protection by tree size, internationally, many cities use minimum diameter requirements (Lavy and Hagelman 2019; Coughlin, Mendes, and Strong 1988; Akmar et al. 2011; Watson 2015). Specifying a minimum diameter requirement reduces public criticism of excessive governmental overreach (Watson 2015). Sometimes height is considered in addition to diameter (Stilgenbauer and McBride 2010; Dunster 1994; Schmied and Pillmann 2003; Watson 2015). In Prague, tree condition is used in conjunction with diameter (Profous and Rowntree 1993) and in Australia, the visual appearance of the tree is also considered (Watson 2015). In other cases, tree protection is based on species, sometimes to protect native trees (Dunster 1994; Larson et al. 2020), and other times to protect those that are economically valuable (Satean 2019).

Many tree protection bylaws have different classes of trees that determine how they are protected. While the presence and content of these classes vary across cities, they are commonly based on tree size, where larger trees are subject to increasingly stringent protection (Profous and Rowntree 1993; Coughlin, Mendes, and Strong 1988; Lavy and Hagelman 2019; K. Pike et al. 2021; Cubbage and Raney 1987). Many cities also have separate protection classes for heritage, or special, trees, which also often have stricter regulations regarding protection. These designations can be based on unusual size or species, aesthetic or cultural value, historical significance, or other factors important to a community (Coughlin, Mendes, and Strong 1988; Lavy and Hagelman 2019; Stilgenbauer and McBride 2010; Dunster 1994; van der Jagt and Lawrence 2019; Bouwer and Gaum Wilma 2000; Schmied and Pillmann 2003; Ivasko et al. 2019; Yener 2022; Ordóñez-Barona et al. 2021).



In addition to stipulating protection by tree characteristics, many cities often also do so by land use type. The most common example of this seems to be where trees are protected on private or public land. While many apply to both public and private land (Profous and Rowntree 1993; Lavy and Hagelman 2019; O'Herrin and Shields 2016; Larson et al. 2020; Schmied and Pillmann 2003), some are specific to just public (Dunster 1994; van der Jagt and Lawrence 2019; Bouwer and Gaum Wilma 2000) or private (Dunster 1994; Lavy and Hagelman 2019) property. However, even when legislation includes both public and private land, there are sometimes further differences by land use, zoning designations, and land development status (Coughlin, Mendes, and Strong 1988; Lavy and Hagelman 2019).

### *3.3.2 Permits and Exemptions*

Even in municipalities with strong stipulations for tree protection, there are often opportunities to obtain tree felling permits or exemptions in the legislation that allow for tree removal. Permits are commonly required to fell trees under urban tree protection legislation in European and North American cities, but the permitting process and ease through which a permit can be obtained varies (Profous and Rowntree 1993; Dunster 1994; Coughlin, Mendes, and Strong 1988; Larson et al. 2020; Lavy and Hagelman 2019; K. Pike et al. 2021). There are also often certain exemptions to these bylaws that undermine their efficacy (Clark, Ordóñez, and Livesley 2020), exempting small or medium trees (Coughlin, Mendes, and Strong 1988), pest plants (Lynch 2022), fruit trees (Profous and Rowntree 1993; Kowalski and Conway 2023; Larson et al. 2020; Schmied and Pillmann 2003), or major land use types (Coughlin, Mendes, and Strong 1988). For example, an ordinance in Ocala, Australia does not apply to single-family residential parcels smaller than three acres (Gatrell and Jensen 2002). In certain circumstances, landowners can also remove a certain number of trees without a permit before protection is required (Dunster 1994). For example, in Nanaimo, Canada landowners can remove 10 trees per year from any parcel of land, which has been a point of contention (Dunster 1994).

### *3.3.3 Measures to Increase Effectiveness*

While there are legal avenues to remove trees protected under legislation, many contain replanting requirements and other mitigation measures to help increase their effectiveness. Requirements to replant trees that have been cut down are common in many North American and European cities (Coughlin, Mendes, and Strong 1988; Lavy and Hagelman 2019; Ordóñez-Barona et al. 2021; Dunster 1994). Many municipalities also require the submission of tree management plans during land development, sometimes resulting in required design changes to proposed structures (Coughlin, Mendes, and Strong 1988; Ordóñez-Barona et al. 2021; Dunster 1994). While the requirements of these plans vary, they typically include the locations of protected trees, their species, and replanting plans for those that cannot be preserved. A study in Australia highlighted that some cities require developers to deposit a bond before development, forfeited if the trees are damaged or removed (Ordóñez-Barona et al. 2021).

Many tree protection bylaws have enforcement mechanisms, as well as processes for monitoring and evaluation, though these seem to be discussed infrequently in the literature. Enforcement is subject to time, resources and the prosecutorial drive of governments that enact them (Dickerson, Groninger, and Mangun 2001; Lavy and Hagelman 2019), which are influenced by temporal trends and contexts (Conway and Urbani 2007; Koeser et al. 2021). Fines are among the most common enforcement mechanisms and are issued to those who violate protection mandates. In the USA, these have been found to range from $500 to $2,000 USD (Lavy and Hagelman 2019). Unfortunately, however, many forms of tree protection legislation lack comprehensive enforcement mechanisms, and thus a majority of violations may go undetected (Coughlin, Mendes, and Strong 1988).

## 3.4 Perceptions

### *3.4.1 Urban Forestry Professionals*

The creation of tree protection legislation is a priority for many community officials and urban forest managers (Driscoll et al. 2015). Considered a core management component (Schoeneman and Ries 1994), legislation is important for successful governance (Wirtz et al. 2021). Even in communities with undeveloped urban forestry or volunteer tree warden programs, ordinances are still common (Stevenson, Gerhold, and Elmendorf 2008; Rines et al. 2010), although ordinance support from municipal officials is higher in communities with more developed urban forestry programs (Stevenson, Gerhold, and Elmendorf 2008). Amongst urban foresters and tree commissioners, ordinances are highly supported (Stevenson, Gerhold, and Elmendorf 2008; W.F. Elmendorf, Cotrone, and Mullen 2003), particularly amongst experienced professionals (Kose et al. 2021), although there is more support for public versus private tree protection ordinances (W.F. Elmendorf, Cotrone, and Mullen 2003). This support may be spatiotemporally variable, however. For example, a 1994 study in Connecticut found 40% of tree activists and elected and municipal officials were resistant to TPOs (Ricard 1994). Similarly, a 2006 study found low support for TPOs amongst New England tree wardens (Ricard and Bloniarz 2006).



#### *3.4.2 Public Awareness and Support*

Residents learn about tree protection legislation from neighbors, local newspapers, tree professionals hired to remove trees, builders performing renovations that require removal of trees, and community groups like neighborhood associations (Conway and Lue 2018). Awareness is lower amongst newer residents (Kaitlyn Pike et al. 2023; Conway and Lue 2018), including awareness of replanting requirements (Kaitlyn Pike et al. 2023); however, they engage professionals to help preserve the trees on their property (Kaitlyn Pike et al. 2023). One study found awareness of legislation is higher amongst those with more trees on their property, those who have previously removed trees on their property, or those who are university-educated (Conway and Lue 2018). Legislative awareness may not ultimately influence actions like tree replacement planting (Conway and Lue 2018; Conway et al. 2022).

Research suggests that public support for tree protection legislation is based on the benefits trees provide to property values, runoff mitigation, and aesthetics (Treiman and Gartner 2005), whereas lack of support is based on the restrictions to personal property rights, lack of trust in government, and increased development costs (Treiman and Gartner 2005; Chen and Hua 2015; Żuk and Żuk 2021). However, some support restricting personal property rights for environmental reasons (Żuk and Żuk 2021) and the majority of community members do not support development when it means the removal of multiple healthy trees (Koeser et al. 2023).

Support for legislation is also higher in larger urban and suburban communities, which are areas that more frequently protect trees during development or require replacement planting (Treiman and Gartner 2005; Conway and Urbani 2007). This is in contrast to smaller and more rural communities that are less likely to have tree protection legislation (Treiman and Gartner 2004) and often have a more challenging time introducing legislation because of the conservative nature of local governments and high debates surrounding private property rights (W.F. Elmendorf, Cotrone, and Mullen 2003). This may be tied to the demographics of these spaces. Support for legislation is higher amongst women, younger voters, and those with a university education and/or higher income (Conway and Lue 2018; Żuk and Żuk 2021). Support is also higher amongst those who have lived on their property for only a few years, while people who have lived in their house for at least 20 years are less likely to support legislation, including regulating private tree removal, permitting, and tree planting (Conway and Lue 2018; Treiman and Gartner 2005).

The public is generally supportive of the ability to remove trees for safety reasons, including dead, diseased, risky, and wildfire-prone trees, and for conflicts with urban life, including impacting infrastructure, delaying development, creating aesthetically unpleasing views, or causing a nuisance (Koeser et al. 2023; Gilbert and Brack 2007). For example, following a

Canberra bushfire, requests to remove protected trees from leased lands increased for one year, then declined to pre-bushfire rates, indicating that leaseholders became more concerned about protected trees following the bushfire (Gilbert and Brack 2007).

There is also diminished support when legislation regulates private tree removal (Conway and Lue 2018; Koeser et al. 2023), although tree replacement requirements may help increase the support for private tree protection legislation (Conway and Lue 2018). There is also greater support for more stringent legislative requirements amongst households with more trees, meaning that legislation may be supported by those most affected by it (Conway and Lue 2018).

## 3.5 Successes

### *3.5.1 Canopy Cover Retention*

A growing number of studies examining success suggests that tree protection legislation is largely considered successful in maintaining and enhancing urban forests. Success can be derived from a number of metrics, including trees protected, canopy preserved, and canopy replaced (Wirtz et al. 2021). Even when trees are permitted for removal, they are often removed in higher canopy cover areas or for diseased or unhealthy trees (Lavy and III 2017). Empirical evidence of the success of tree protection legislation can be drawn from areas with current or former legislation. For example, the laxing of tree protection legislation in Poland resulted in the subsequent felling of 20,000 trees in Warsaw (Żuk and Żuk 2021) and 5,075 trees in Racibórz (Zięba-Kulawik et al. 2021), predominantly at the hands of construction and development companies (Żuk and Żuk 2021). Other studies have employed statistical models, finding that tree protection legislation contributed to increased urban canopy cover (Salisbury et al. 2022; Hill, Dorfman, and Kramer 2010; Hilbert et al. 2019; Landry and Pu 2010; Lee, Longcore, and Wilson 2010). However, Galvin and Bell (2004) found the presence of an ordinance did not relate to a higher quantity of trees (Galvin and Bleil 2004). Similarly, Heynen and Lindsey (2003) found that urban forest policies, including ordinances, were not significantly correlated with canopy cover (Heynen and Lindsey 2003). Additionally, in comparing a city with tree protection legislation and a city without, Sung (2012) found that while mean canopy height statistically differed between the two cities, percent canopy cover did not (Sung 2012).

Of the studies that did find legislation contributed to canopy cover, Hill et al. (2010) found that for each clause an ordinance contains, of which they examined nine, there is an expected 1.03% increase in canopy cover over ten years (Hill, Dorfman, and Kramer 2010). Similarly, Lee et al. (2010) found that the proportion of green cover was positively correlated with the number of tree ordinances (Lee, Longcore, and Wilson 2010). Landry and Pu (2010) found that tree canopy cover increased on parcels built after the adoption of an ordinance in 1974 versus the five years prior (Landry and Pu 2010). However, while Salisbury et al. (2022) found that the presence of tree preservation and heritage tree ordinances are significant predictors of Floridian urban tree canopy, only heritage tree ordinances were a significant predictor when examining built areas within municipalities (Salisbury et al. 2022). Similarly, another study in Florida found that only two factors predicted urban tree canopy cover: housing density and the presence of a heritage tree protection ordinance. An increase in 500 housing units per km$^2$ would predict a 1.1% decrease in canopy cover while the presence of a heritage tree protection ordinance was associated with a 6.7% increase in canopy cover (Hilbert et al. 2019). In Falls Church, Virginia, Chojnacky et al. (2020) found that tree retainment and replanting requirements resulted in canopy cover targets for private property being met 10 years after development (Chojnacky et al. 2020). These findings have been used to justify the recommendation for adoption of specific policies and legislation in other regions experiencing canopy cover loss (Kanniah and Siong 2017).

### *3.5.2 Planning and Development*

The implementation of tree protection legislation can help preserve select trees to the benefit of community character and aesthetics, making them valuable tools for planners (C. Duerksen and Goebel 1999). Planning organizations like the American Planning Association have helped discuss how to implement legislation in support of the planning and development process (C.J. Duerksen and Richman 1993). Similarly, Birmingham, England developed its tree protection legislation with specifications for water-sensitive urban design (McEwan 2018).



In addition to planners (C. Duerksen and Goebel 1999), developers and construction companies base their tree removal and retention decisions on legislation (Willis et al. 2024). In cities with tree protection legislation, developers and construction companies are more likely to reduce tree-damaging practices during construction, more likely to preserve trees, and more likely to plant trees after development (O'Herrin et al. 2022). These actions are driven by legislative requirements, rather than developer knowledge of tree preservation or a conscious effort to preserve trees (O'Herrin et al. 2022). In some cases, legislation can complement the preferences of developers who often prefer trees that are characteristic of the region – often those protected by legislation – rather than short-lived or construction-vulnerable trees (Willis et al. 2024).

Legislation also provides economic benefits for arboricultural companies because they are often engaged by developers and construction companies during residential construction to help preserve trees and develop tree inventories required by legislation to obtain building permits

(O'Herrin et al. 2022). Tree protection legislation can also lessen market incentives for unethical tree care practices. In the absence of bylaws, ordinances, or other regulations, tree companies following voluntary best practices can be negatively impacted economically when other companies are willing to work unethically (Martin and Almas 2023).

## 3.6 Challenges

### *3.6.1 Writing and Development*

Several challenges impeding the usefulness of tree protection legislation have been identified in the literature. Common issues within legislation include unclear language and organization, ambiguous terms, lack of measurable objectives, lack of training and education, insufficient public input, and internal contradictions (Neupane et al. 2022). In the absence of guidelines accompanying the legislation, they can be challenging for people to interpret (Nik Mohamed Sukri, Othman, and Wan Ariffin 2017). Their success is also influenced by the competence and commitment of the government responsible for reviewing permit applications, and low competence or commitment can decrease the success of the legislation (Profous and Rowntree 1993).



During the development stage between when legislation is introduced and officially enacted, panic can result in increased tree felling as landowners rush to clear land before they are no longer legally able, as documented in Surrey, British Columbia (Dunster 1994). Conflict also arises due to a lack of technical understanding between the public and politicians about what types of trees should be protected, when arborists need to be consulted, and exceptions for unsafe or nuisance trees (Dunster 1994).

In addition to the challenges of urban forest protection for governments, there are also environmental justice issues associated with tree protection legislation. Both tree protection and zoning ordinances influence urban canopy cover, yet neighborhood-based canopy cover standards are subject to local lobbying efforts. While this allows for local input, it can exacerbate disparities in urban forest protection in the absence of lobbying by under-resourced, marginalized communities (Kolosna and Spurlock 2019).

### *3.6.2 Insufficient or Conflicting Policies*

Once enacted, the efficacy of enacted tree protection legislation can be constrained by insufficient or conflicting policies, laws, and regulations, both within and across various levels of government. In certain cases, tree protection legislation can be nullified by other acts (Sukri et al. 2023; Koeser et al. 2021). Efficacy can also be limited by insufficient protection mechanisms or legislation exemptions (Lavy and Hagelman 2019).

Local regulations can be constrained by higher levels of government through planning policies, development targets, and financial resource allocation (Wood 2004). For example, pro-development cultures at the state or provincial level can include removing the decision-making authority of municipalities or counties (Wood 2004; Koeser et al. 2021). A related issue arises when two states differ in their protection of urban and peri-urban forests. For example, *Aquilaria sinensis* (incense tree) is protected in Hong Kong but not mainland China, resulting in extirpation of *A. sinensis* from mainland China but not Hong Kong (Jim 2015). This has driven illegal poaching of agarwood, a fragrant wood caused by mold infections in *A. sinensis*, in Hong Kong's peri-urban forest (Jim 2015).

### *3.6.3 Enforcement and Legalities*

Enforcement poses an additional challenge, even for well-written legislation. Unlawful behaviors arise, despite legislation explicitly prohibiting cutting, removal and grafting (Kowalski and Conway 2023). One source of such issues is enforcement overburdening. When regulating to the individual-tree scale, tree officers have to respond to many requests by property owners for pruning trees, rather than focusing on developers removing trees en-masse (Barrell 2015). There are also instances of tree protection legislation not being enforced or violators not being prosecuted (Nik Mohamed Sukri, Othman, and Wan Ariffin 2017; W.F. Elmendorf, Cotrone, and Mullen 2003; Andresen 1976; Jim and Liu 2000). Time constraints, jurisdictional issues, subjective enforcement, and limited financial and personnel resources limit the enforcement of legislation (W.F. Elmendorf, Cotrone, and Mullen 2003; Stobbart and Johnston 2012; Jim and Liu 2000; Clark, Ordóñez, and Livesley 2020). For example, Elmendorf et al. (2003) found that 20% of Pennsylvanian commissions with street tree legislation did not enforce them. In Ontario, Conway et al. (2022) found that 30% of those issued permits had not planted the required replacement trees (Conway et al. 2022). Also in Ontario, McWilliam et al. (2014) found that trees were removed and residents encroached on the urban forest edge, despite legislation prohibiting such encroachment (McWilliam et al. 2014). However, some non-enforcement occurs because an activity – like guerrilla gardening, the practice of growing plants on another person's property without permission – is a widely supported endeavor and environmentally beneficial (Millie 2022).

A potential legal issue also arises when tree owners and the government differ in risk perceptions, which is a common sentiment as professionals think that private landholders exaggerate tree risk (Clark, Ordóñez, and Livesley 2020; Kirkpatrick, Davison, and Harwood 2013). Mitigating hazardous trees is an important legal responsibility of tree owners (Mortimer and Kane 2004). Sometimes, however, trees considered a risk by the homeowner do not meet the risk threshold of the government issuing the permit. If the government authority is binding and the tree owner is unable to take action due to legislation, the duty of care or legal risk may be passed to the authority, although this is rare (Weick 2012). In a complementary challenge, nuisance or disturbance trees may be protected by tree protection legislation or regulations. Here, the tree owner may be relieved of liability to the injured party if the government agency prohibits the removal of the tree (Weick 2012). These issues are further challenged by boundary trees located on or adjacent to a property line can blur legal obligations, varying by jurisdiction (Weick 2012).

#### *3.6.4 Conflicts with Private Property Rights*

Bylaws also have the potential to become politically polarizing. During and following the introduction of municipal tree protection bylaws in British Columbia, Canada in the 1990s (Dunster 1994), criticism arose that tree preservation bylaws restricted the property rights of homeowners. Conservative media framed the Vancouver bylaw as ecologically questionable, citing a 4:1 replanting rate, and exacerbating racial tensions, citing conflicting values between Asian and Caucasian communities (British Columbia Report 1996). According to a *BC Report* article, the former defended their property rights while the latter prioritized the environment (British Columbia Report 1996).

The criticism of the impact on private property rights has also occurred following socio-political shifts. After the 2015 Polish election of right-wing populist party Law and Justice (PiS), Poland enacted the *Nature Conservation Act* (2017), prioritizing private property rights over the conservation of privately owned trees (Żuk and Żuk 2021). Environmental issues were deprioritized over the economy, modernization, and development. This included opening public, urban greenspaces for development and, as of January 1, 2017, removing permitting requirements for the removal of trees and shrubs on private property. The publicized reason for removing the permit requirement was that it reduced bureaucracy as permits were largely granted anyways. The permits were also believed to be excessive, unjustifiably interfering with property ownership. As a result of the change, more than three million urban and forest trees were removed in Poland (Zięba-Kulawik et al. 2021; Żuk and Żuk 2021). Urban forest ecosystem services in Poland declined as a result of the weakened regulations (Zięba-Kulawik et al. 2021).

More recently, the predominantly Republican Florida Legislature substantially limited the breadth and enforceability of tree protection ordinances by municipalities, citing concerns about the undue burden that the ordinances had on personal property rights (Florida House of Representatives 2022). The revised legislation now prohibits municipalities from requiring permits to remove a tree deemed dangerous by an arborist and prohibits municipalities from requiring trees be replanted (Koeser et al. 2021). With the popularization of civic libertarianism within conservative groups (Yadav 2021) and the politicization of housing (Lancione 2020) and transportation infrastructure development (Audikana 2021), trees have become a source of conflict, propelling tree protection bylaws into the socio-political sphere (Dempsey 2023).

### 3.7 Recommendations for future research

Current research on tree protection legislation is broad, providing an overview of international legislation surrounding urban tree preservation. While we only reviewed English-language articles, the lack of articles from Africa and South America may indicate geographical biases that limit the international perspective in urban forestry. Additionally, the articles reviewed are primarily case studies or limited to a single region. As a result, it is unclear if the literature reflects the breadth of legislation, particularly given the noted geographic limitations. More comparative studies and broader surveys of legislation, like Ordóñez-Barona et al. (2021), are needed to understand the characteristics of tree protection legislation that has been adopted globally. Methods for examining legislative scope are consistent, and few studies take unique approaches that provide novel insights. Dickerson et al. (2001) provide a good example of a unique study, examining the association between community characteristics and ordinance scope (Dickerson, Groninger, and Mangun 2001). In addition to the content of the legislation, further research should also examine methods of monitoring and enforcement. Best practices for monitoring and enforcement may substantially elevate the efficacy of current approaches.

Alongside the development and enforcement literature, further research should examine the socio-legal aspects of tree protection legislation. Areas like equity considerations remain largely unexplored, yet research in these areas would have key implications for policymaking. Similarly, no identified study examined the perspectives of private tree companies. Anecdotally, there appears to be resistance to tree protection legislation from tree companies. When a tree protection bylaw was introduced in Vancouver, British Columbia, a conservative newspaper quoted a representative of a multi-national tree company explaining how to kill a tree in a manner that would not be detected (British Columbia Report 1996). If there is widespread resistance to tree protection bylaws amongst arborists, the private sector may be undermining tree protection legislation by illegally removing trees for landowners.

Additionally, socio-political shifts that prioritize private property rights should be examined. It would be valuable to understand how urban foresters react to socio-political pressures.

Equally valuable would be more geographical diversity that would highlight tree protection ordinances under yet-unexplored socio-political systems.

Lastly, studies examining the efficacy of tree protection legislation are lacking. Methodological errors or limitations, inherent in contrasting two or more cities, may drive results that misidentify legislation as contributing to canopy cover retainment or increases, rather than tree-positive sentiments in cities that implement legislation. As remotely sensed inventory methods like light detection and ranging (lidar) become more common place, future studies examining legislative efficacy can consider additional variables besides canopy cover. Trunk diameter, estimated biomass, and mean canopy height are becoming increasingly accessible metrics, which is important because, as Sung (2012) points out, canopy cover may not accurately compare retained trees versus juvenile planted trees (Sung 2012). However, because urban forest inventory data is limited in many smaller cities, mixed-methods research will remain necessary to avoid limiting legislative research to only large urban areas.



## 4. Conclusions

In this systematic review, we examined existing literature on the regulatory mechanisms used to protect urban trees internationally. Findings support that urban tree protection legislation varies, differing in how it is developed to how it is specified and implemented. These regional variations are not only reflective of the diverse historical processes that support legislation but are also crucial to the success of these mechanisms in protecting the urban forest. On-going challenges like underenforcement, conflicting legislation, and low resource availability impede the efficacy of tree protection legislation. By highlighting the conflicts and areas for improvement, this review provides beneficial insights for those using and researching urban forest regulatory mechanisms. Proactive responses to dynamic socio-political and socio-legal issues alongside improved structure, enforcement, and monitoring of the urban forest can contribute to the sustainability of nature in urban spaces.

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