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**Stewarding street trees for a global urban future:
Paris, Taipei, and Washington, D.C.**

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Introduction

Street trees are one of the most prominent types of plants in the urban public realm. They define the street corridor, humanize the scale of cities, calm traffic, separate walkers from vehicles, and filter sunlight all while softening the urban fabric and introducing beauty in the form of flora. Importantly, trees can transform streets from utilitarian transportation corridors into places in which people want to be (Massengale & Dover, 2014). This is especially important as human beings become an increasingly urban species; 2008 marked the first time that more people worldwide lived in urban than rural areas, and by the end of this century some three-quarters of humanity is projected to live in cities (Angel, 2012), leading the contemporary era to be described as the “first urban century” (Hall & Pfeiffer, 2000, p. 5).

In this dawning age of cities (Young & Lieberknecht, 2019), people spend the vast majority of their time indoors (Brasche & Bischof, 2005; Klepeis et al., 2001). Streets are by extension one of our most common experiences of outdoor settings, and these ‘travelscapes’ represent an excellent opportunity to provide urban populations with the health and well-being benefits of nature contact, as evidenced by a robust body of literature (Frumkin et al., 2017; Hartig et al., 2014; Kuo, 2015). This dovetails with increasing interest in urban greening, defined as a social practice of organized or semi-organized efforts to introduce, conserve, or maintain outdoor vegetation in urban areas (Eisenman, 2016b; Roman et al., 2020). Greening includes a range of initiatives, policies, and incentives to vegetate the landscape of cities (Beatley, 2016; Tan & Jim, 2017), and it often includes ambitious tree planting initiatives (Eisenman et al., 2021; Nguyen et al., 2017; Young, 2011). Of note, the systematic citywide planting of trees along streets was not common in most European and North American cities until the late 19th and early 20th centuries (Campanella, 2003; Dümpelmann, 2019; Laurian, 2019), but it has since become commonplace around the world (Lawrence, 2006).

Yet, the actors and norms that guide street tree planting and management can vary in different cultural contexts. In North America, for example, urban forestry has traditionally focused on street trees, whereas European definitions of urban forestry relate more to forest ecosystems such as woodlands in or near cities (Konijnendijk et al., 2006). One study found substantial differences in why and how municipal leaders in North America and Scandinavia conduct inventories of urban trees. In both places, street trees figured prominently in urban forest

inventories, and study participants mentioned operational planning and arboricultural maintenance as important rationales for this work. However, in North America citizen volunteers were important actors in conducting urban tree inventories, and this volunteer work may have spurred subsequent citizen engagement in local urban forestry activity. North American cities also emphasized a range of economic, environmental, and social benefits of urban trees as rationales for conducting inventories. In Scandinavian cities, by contrast, these benefits were not mentioned or recognized as important rationales for conducting urban tree inventories, nor did citizen volunteers participate in this work (Keller & Konijnendijk, 2012).

International dimensions are also important considerations when accounting for street tree planting and stewardship. While research suggests a basis for universal landscape preferences predicated on a shared evolutionary past (Appleton, 1975; Ulrich et al., 1991), and studies consistently show reductions in stress when people have contact with vegetated landscapes (Frumkin et al., 2017; Hartig et al., 2014; Kaplan & Kaplan, 1989)—including local trees (Suppakittpaisarn et al., 2019)—people have different perceptions of, and preferences for, urban trees (Konijnendijk, 2008; Zhao et al., 2017). The same holds true for street-level vegetation. In Sapporo, Japan, for example, researchers found that people preferred sidewalk planting beds of flowers *without* trees over similar planting beds *with* trees (Todorova et al., 2004). By contrast, a study spanning four cities in the Netherlands found a strong preference for large trees along streets (Van Dongen & Timmermans, 2019), while a study in Australia found that homes on streets with more than six different street tree species had reduced sale prices, suggesting a threshold beyond which people in this place will accept a diversity of street tree types (Plant & Kendal, 2019). In Hong Kong, 94% of survey respondents supported street tree planting, but the most preferable streetscape attribute was high visual permeability (the openness of the street), suggesting that street trees should not be too large or too densely spaced.

International differences extend beyond landscape vegetation preference. For example, a comparative analysis of five capital cities in countries spanning three continents found substantial differences in street tree density and distribution; moreover, differences between cities in the same climate zone suggest that place-specific cultural dimensions such as urban form, aesthetic norms, and governance regimes are important factors in the density and distribution of urban street trees (Smart et al., 2020). People within a given city can also hold different perceptions of—and receptivity to—tree planting campaigns. In Detroit, Michigan, many neighborhoods targeted for street tree planting resisted such efforts, and this was explained by a lack of ‘procedural justice’ and differing ‘heritage narratives’ (perceptions of local history) between local residents and tree planting advocates (Carmichael & McDonough, 2019).

The aforementioned distinctions illustrate the importance of comparative research on street tree planting and management, especially as greening (and associated constructs such as green infrastructure, ecosystem services, and nature-based solutions) becomes a common approach to planning for 21st century cities worldwide. Unlike non-comparative research, comparative scholarship seeks to illuminate differences and similarities between the objects of analysis—in this case street trees—and their contextual conditions, such as culture and nationality. Comparative research can also illuminate the embedded customs and assumptions of a given place, which is especially important if they are taken to be universal (Esser & Vliegthart, 2017; Lewis-Beck et al., 2004). This is noteworthy in a globalizing world characterized by the

widespread diffusion of information, values, and norms (Castells, 1996). Vernacular distinctions are also important in an urban environmental discourse that is significantly influenced by Anglo-American and European tradition (Anguelovski & Martínez Alier, 2014; Eisenman, 2016a; Ernstson & Sörlin, 2019).

This chapter seeks to enrich this conversation by offering brief case studies and comparative analysis of the typical actors and practices related to stewardship of urban street trees in three cities on different continents: Paris, France; Taipei, Taiwan; and Washington, D.C. in the United States. Each of these cities is the capital of their respective countries, so each subsection opens with a brief narrative addressing national and historic context. Each of these cases addresses both mature and newly planted street trees; and the respective cases draw upon a combination of academic literature, professional documentation, and select interviews with local experts.

Paris

National & Historical Context

The French tree-lined street and boulevard model was diffused throughout Europe and the Americas in the 18th and 19th centuries, and it is highly influential to this day. Within France, tree planting and management practices diffused from Paris to the provinces, reinforcing the special emphasis on Paris in this section. Until the 19th century, street tree planting decisions were made by kings and nobility. In Paris, Kings Charles V (14th century), Henri IV, Queen Marie de Medici (17th century), and Louis XIV and Louis XV (17th and 18th centuries) had rows of elm, plane, linden and mulberry trees planted at regular intervals along select streets, canals, ramparts and boulevards (Dorion, 2014; Lavedan, 1993; H.W. Lawrence, 1993, 2008). The first tree-lined promenades and boulevards include Henri IV's tree-lined mails and Marie de Medici's Cours-la-Reine. The latter, planted in 1628 and still in existence as part of the Tuileries Garden, comprised three long alleys lined with 1600 elms planted four meters apart. This has been described as creating the first urban tree canopy over pedestrians and vehicles (Bergeron, 1989; Forrest, 2002; Forrest & Konijnendijk, 2005).

The French Revolution of 1789 shifted power over urban trees. Beyond the 60,000 Liberty Trees (mainly oaks and poplars) planted throughout the country as a political symbol, the Revolution laid the foundation for municipal governance. Since the 19th century, French urban tree planting and management has been under the purview of municipal agencies. An exception, however, is Paris, which remained under national control until 1977. Prior to this, the capital city was managed by prefects appointed by kings, emperors and presidents, including Claude-Philibert Barthelot, Count de Rambuteau, and George-Eugène Haussmann who expanded the tree-lined boulevard model throughout the city (Jones, 2006; Laurian, 2019; Lawrence, 2008).

Contemporary Paris

Today, Paris' street trees are managed by the Service of Trees and Woodlands (Service de L'Arbre et des Bois) of the Municipal Direction of Green Spaces and the Environment (Direction des Espaces Verts et de l'Environnement, DEVE). The DEVE answers directly to the mayor and city council.(Ville de Paris, 2019a). The agency's 3,100 employees manage trees, including street trees and trees in more than 500 green spaces, two woodlands, a municipal nursery, 20 cemeteries, sports centers, and primary schools, with a €33 million (\$38.9 million) operating budget in 2018 (Ville de Paris, 2018a). Its staff includes planners, public outreach specialists,

landscape designers (aménagement paysagers), and arborists (arborists-élagueurs), many of whom are certified arborists trained at the Paris School of Horticulture and Arboriculture (Ecole du Breuil des Arts et Techniques du Paysage). The DEVE partners with other municipal agencies, e.g., on the Paris Climate Plan, and with national agencies, e.g., the National Agency for Biodiversity.

While Paris' street tree planting is solely undertaken by municipal DEVE staff and funded through the municipal budget, the city also implements participatory programs. The Green Hand program (Main Verte), launched in 2003, supports 134 resident-led community gardens. Through the Greening Near My Home program (Du Vert Près de Chez Moi), launched in 2014, residents can suggest greening interventions for specific sites in their neighborhoods (Ville de Paris, 2020a). Of 1,500 proposals, 209 have been selected for implementation thus far and these include green walls, potted plants, and additional tree plantings conducted by municipal services. Residents can also apply for innovative Greening Permits (Permis de végétaliser) which allow them to garden in public spaces on sidewalks. Residents can install potted plants or grow micro gardens, typically flowers and herbs, in street trees' planting beds (see Figure 1). Permit holders are responsible for planting, watering and maintenance, and they must publicly post their permit. A dedicated online interactive map provides the list, location, and photos of these resident-led projects (Ville de Paris, 2020b).



Fig. 1: Resident-led greening of street tree planting beds. Sources from left to right: 1/ Ville de Paris, H. Jarry, <https://www.paris.fr/pages/un-permis-pour-vegetaliser-paris-2689>; 2/ Ville de Paris, Victor Connan, <https://www.paris.fr/pages/un-permis-pour-vegetaliser-paris-2689>; 3/ Lucie Laurian; 4/ Lucie Laurian

Tree inventories and numerical tree planting goals drive urban forestry practices in French municipalities, including Paris, which aimed for 20,000 additional trees along streets and in parks and gardens between 2014 and 2020 (15,000 were added as of 2019). Of note, the newly reelected mayor ran on an ambitious platform of 170,000 more trees between 2021 and 2027, many of which will presumably be planted on streets. Currently, the city has on average 4.9 trees for every 100m of street, but trees are not evenly distributed across street types: collector streets have nearly three times as many trees as local streets (Smart et al., 2020). This is likely due to the narrow width of many streets in Paris, whose underlying settlement dates back some two millennia (Bournon, 1888).

Programs to increase Paris' tree counts date back to Haussmann's projects and have steadily increased since then. The city had 38,000 trees in its first inventory in 1855, 88,000 by the end of the 19th century (Landau, 1992), 96,000 in 1993, and 106,000 in 2020. In total, Paris is home to 504,000 trees: 106,000 street trees, 48,000 trees in 490 parks and gardens, 32,000 in cemeteries, 6,000 along the périphérique highway, 7,000 trees in municipal schools and day care centers, 4,000 in sports complexes and 300,000 in two woodlands. Since 2014, Paris' award-winning tree inventory—Paris Arbres Opendata, available online—includes for each tree the species and genus, planting date/age, size, health conditions, watering, pruning, and removal schedule. The database tracks data in real time, and is used for planning, analysis, and public information. The city also maintains a separate inventory of trees of special significance (*arbres remarquables*), noteworthy for their historical significance or morphology.

Paris' street trees are grown in a municipal nursery, the 44ha municipal Horticulture Center, which provides about 80% of the city's plants and trees, meaning that Paris controls its tree source and supply. Street trees are planted when they are 5 to 10-years-old in about 12m³ of soil. Once planted, trees are staked, watered, and regularly pruned for three years. After this, trees are pruned to clear traffic signals, and remove low branches and dead limbs. All Paris' trees are inspected annually and one fifth of trees receive a detailed diagnostic, the results of which are noted in the Arbres Opendata inventory.

Best management practices (BMPs) in urban tree management are implemented under the guidance of several charters. Paris signed the Regional Charter on Biodiversity and Natural Milieus in 2004, which commits the DEVE to supporting regional flora, fauna, and natural habitats, reducing mowing, introducing ponds and wetlands, planting native species, and limiting herbicides and pesticide use. The charter also commits the DEVE to considering street trees as living species rather than formal elements of urban design—which represent an important shift in ontological framing—leading to guidelines for planting diversified and native species, reducing pruning, adapting planting and maintenance to each species, and tracking tree maintenance. Paris' parks and gardens can also qualify for the Ecological Green Spaces label (Espace Verts Ecologique). This designation implements the 1994 Aalborg Charter for European Sustainable Cities, the 2004 Regional Charter on biodiversity and natural milieus, the 2017 Paris Climate Plan (Plan Climat, Air, Energie), and the 2018 Paris Rain Plan (Plan Paris Pluie). For street trees, this translates into reduced pruning and chemical applications, and providing larger naturalized tree planting beds with native grasses and wildflowers where possible (Laurian, 2012).

Beyond inventories and BMPs, the century-old practice of creating linear monocultures and regularly-spaced street tree alignments (*arbres d'alignement*) has a long-lasting legacy. Original tree alignments generally relied upon one species to ensure formal regularity, and trees were planted all at once to ensure similar sizes. The most common species were elm (*Ulmus minor*, *campestris*, *pumila* and, to a lesser extent, *sapporo gold* and *americana*), planetree (*Platanus acerifolia*) and linden/lime (*Tilia*) trees selected for their fast growth, wide canopies and resistance to urban constraints and heavy pruning (Ville de Paris, 2019b). Today, 58% of all street segments in Paris remain single-species (Ville de Paris, 2019a). Alexandre Jouanet, head of the Service des Arbres et Plantations under Haussmann, led early diversification efforts: half of the street trees his agency planted were planes and elms, but he diversified the mix with Horse chestnuts (*Aesculus hippocastanum* and *Aesculus hippocastanum baumaii*), American walnuts

(*Juglans nigra*), Tree of heaven (*Ailanthus altissima*), and Pagoda trees (*Sophora japonica*). Today, 37% of Paris' street trees are planes, 15% horse chestnuts, 10% linden, 10% pagoda trees, 3% maples, and 3% ash (Atelier Parisien d'Urbanisme, 2010).

Diversification occurs with the tree replacement cycle. The Paris DEVE replaces 1,500 street and 1,500 park trees annually. Newly planted trees include 190 species, including regionally native species and Mediterranean species adapted to climate change. The Paris 2018-2024 Biodiversity Plan guides tree selection and management (Ville de Paris, 2018b). It also highlights ecosystem functions provided by urban trees and associated goals related to climate change mitigation and adaptation (especially heat waves and urban heat island effects); air quality; stormwater runoff management; support for pollinators and wildlife; and biodiversity goals set in the 2016 national law on Biodiversity, Nature and Landscapes (*Loi pour la reconquête de la biodiversité, de la nature et des paysages*) and the 2009 Regional Ecological Plan (*Schéma Régional de Cohérence Écologique*). This is consistent with the National Environment Agency (*Agence de l'Environnement et de la Maitrise de l'Energie*) which refers to urban trees as “climate actors” (ADEME, 2018).

The 2018-2024 Biodiversity plan has also set a goal to assess Paris' canopy cover, and then to increase it by 1% by 2024 and 2% by 2030. This falls short of setting an actual numerical canopy cover goal (other French cities, in contrast, have adopted canopy cover goals, e.g., Lyon at 30% by 2030). Paris's canopy cover provided by street trees (excluding all parks and gardens) varies across district, from 0.5% to 3.5% when dividing the street tree canopy cover by each district's total land area, and from 2% to 11% when dividing the street tree canopy cover by district's street area, i.e., excluding buildings' footprint (Atelier Parisien d'Urbanisme, 2010). The MIT Green View Index (GVI), on the other hand, assesses the pedestrian perspective based on Google Street View panoramas. Among the 27 large cities investigated using this method, Paris has the lowest GVI at 8.8% (MIT Senseable City Lab, 2020). Given Paris' very high density—over 20,000 residents/km² compared to London (4,500/km²), Amsterdam (4,900/km²), Berlin (3,800/km²), and New York City (10,200/km²)—increasing canopy cover will require creative solutions.

In 2019, Mayor Anne Hidalgo announced the creation of new “urban forests” with 2,000 trees set to be planted at key landmark locations: in front of the Hotel de Ville, behind the Opera Garnier, at Gare de Lyon, and along the Seine. This is predicated on goals to reduce urban temperature and to decrease the amount of impervious cover (O'Sullivan, 2019a). Similar projects such as the 1993 Coulée Verte, which transformed a 4.7km of railroad tracks into a linear garden, and the 1994 Jardin Atlantique with 150 trees planted above railroad tracks, suggest that the new tree planting campaign can be successful. The city is also removing asphalt (12.5ha removed by 2020) to increase permeability, in concert with the Paris Rain Plan. These stormwater infiltration projects, often in schools and street medians, create new tree-planting opportunities (Ville de Paris, 2019b).



Fig. 2: Pruning and pollarded street trees in Paris. Left image source: Ville de Paris, Pierre Viguié: <https://www.paris.fr/pages/chancres-couleur-du-platan-paris-sous-surveillance-7476> Right: Pollarded lane trees <https://pixabay.com/fr/photos/paris-france-trottoir-arbres-hiver-90938/>. Licence: Pixabay (Free for commercial use, no attribution required).

Planting and managing street trees in Paris presents distinct challenges beyond urban density and underground utility and subway infrastructure. Some urban spaces were designed with the explicit exclusion of trees to preserve uninterrupted views of certain monuments and Beaux Arts facades, e.g., Place des Victoires, Place Vendôme, Rue de Rivoli, Avenue de l'Opéra. Popular pressure could change this. For instance, Place des Vosges was designed without trees in 1605 and its first trees were planted 200 years later at residents' requests. In addition, tree pruning and shaping practices have strong cultural roots and values (see Figure 2). In France, as in other European countries, linden and plane trees are heavily pollarded, a practice of removing the upper branches of a tree (Pacini, 2007). This reduces trees' height and crown size, and can give form to outdoor spaces, e.g., linear edges delineating allées with 'walls,' creating 'rooms' and 'curtain' effects, and dense canopies that create outdoor 'ceilings.' Pollarded linden and plane trees are also a staple of French gardens and squares, e.g., at the Palais Royal and Jardin des Plantes; but extreme pruning practices are increasingly challenged today (Toussaint et al., 2002). This highlights the extent to which urban street trees in Paris and France are increasingly understood today as living organisms that serve a range of goals including biodiversity, sustainability, urban design, and cultural heritage.

Taipei

National & Historical Context

Historically, Taiwanese society has a long tradition of stewarding trees in public places such as temple squares. Long-lived trees and those associated with local legends have even been revered as holy or god-like. In some cases, villagers built small temples to worship tree spirits and pray for more prosperous lives for individuals, families, or the community. However, for contemporary Taiwan, trees became commonplace elements of the urban streetscape during Japanese colonial rule between 1895 and 1945.

During this colonial period, Taiwanese culture and urban form were heavily influenced by Japan, and the entire island (395 km long and 145 km across at its widest point) essentially served as a design laboratory for Japanese architects and urban designers trained in the West. Street trees became important urban design elements during this early 20th century period of Japanese rule

(Tashir, 1920). Initially, four types of trees gained special prominence for street planting: *Salix glandulosa* var. *warburgii*, *Alnus formosana*, *Pandanus odoratissimus*, *Bambusa stenostachya* (Ao, 2000). But by the 1920s, more than fifty types of trees were commonly planted along Taiwanese streets. These plantings were noteworthy elements—symbolically and in practice—of a broad movement by the Japanese colonial government to modernize Taiwanese cities.

Nationwide today, trees along major highways are managed by the federal Ministry of Transportation and Communication (MOTC). However, urban street tree planting and stewardship in Taiwan is managed at the municipal level, and each city (often in collaboration with county administrators) prepares management plans that are endorsed by local elected councils. The island spans humid subtropical and tropical climate zones, and has moist, hot summers from May to October, with rainstorms and occasional typhoons, and average high temperatures in July of 34C. Taiwan also has a strong cultural tradition of socializing outdoors. In light of these combined factors, street trees and shaded parks and plazas are highly valued.

Contemporary Taipei

In Taiwan's capital, Taipei, street trees are the sole responsibility of the Horticultural Engineering Team (HET) of the Park and Street Lights Office (PSLO) in the Public Works Department (PWD). Of the 196,000 trees on public land in Taipei City, roughly 89,000 are street trees; due to recent plantings, this is an increase from 88,000 street trees in 2017 (Taipei City, 2019). Of these trees, most are individually tagged and registered in a central database (see Figure 3). The HET is responsible for the daily management of these trees, but this office also subcontracts urgent tree pruning activities to private contractors during the typhoon season from July to September. In 2020, the PSLO allocated 18.1 million USD for all matters related to horticultural management of street trees, parks, and open spaces (R. Mo, personal communication, August 20, 2020).

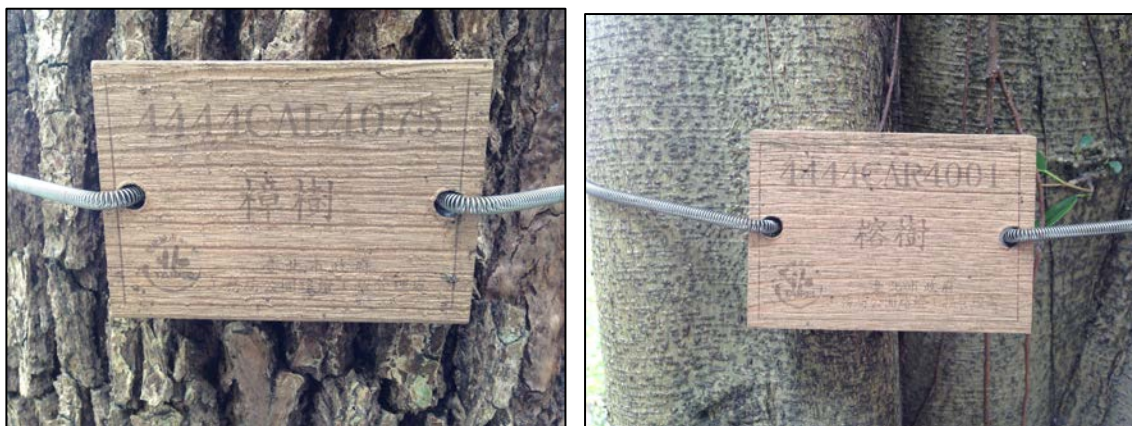


Fig. 3: Street trees in Taipei tagged and recorded by the city. Source: Theodore S. Eisenman.

The HET currently includes 250-260 staff members who manage the city's street trees based on area quadrants (east, west, north, south), each of which is managed by a section leader. This includes some 150 trained arborists who do most of the hands-on work including pruning, weeding, fertilizing, and disease control (Taipei City, 2017). Taiwan has three different systems for training and certifying arborists: municipal level; federal level; and through the Taiwan

Arboriculture Society which is based on standards developed by the International Society of Arboriculture (ISA). In the case of Taipei, the city recruits entry-level applicants through written and physical tests, after which they proceed through two levels of training and certification. In addition to certifying HET staff, subcontractors from private companies can also enroll in HET-led certification classes, which allows contractors to work on the city's tree management projects.

Both the city of Taipei and the federal Forest Bureau publish tree trimming and maintenance guidelines for arborists to follow. Historically, this has been especially important prior to and during the annual typhoon season from roughly June to October. However, climate change is altering seasonal patterns, and typhoon scale storms are becoming increasingly common throughout the year. This is creating maintenance challenges for the municipality, leading the city to initiate efforts to broaden the network of actors who steward trees. As of 2015, for example, Taipei allows schools, neighborhood leaders, nonprofit organizations, private companies, and individuals to adopt trees along streets and in parks and other public spaces; but most adoptees are private companies and local leaders (*lizhang*) of neighborhood groups called *li*. A distinct aspect of Taiwanese society is the establishment of formal neighborhood groups at the sub-district level called 'li,' each of which has an elected leader called a 'lizhang.' In Taipei, there are 12 districts and 456 lizhang. The aforementioned tree adoption program consists of watering, weeding, fertilizing, monitoring tree health, and reporting tri-annually to the HET. If qualified adoptees do not meet certain management criteria, the HET can remove them. In 2016, 455 agents adopted trees in 440 locations across the city including parks, open spaces, and streets. The municipality estimates that this saved the city about 1.7 million USD (Xiao, 2016).

In addition to the aforementioned voluntary stewardship, the city's efforts to maintain street trees can create disputes among citizens, city officials, and other stakeholders. As tree canopies grow, they can block street lights, requiring pruning to maintain sightlines and associated traffic and pedestrian safety. Many shop owners also believe that trees in front of their stores do not align with spatial design principle of *feng-shui*, one of which holds that doors and passages should remain open, as this brings prosperity. This often requires tree planting teams to compromise with shop owner requests to move tree planting holes from directly in front of store entrances, even when the trees are located across several lanes of traffic in planted medians. To facilitate response to citizen complaints, the city provides a reporting system by phone and internet. In 2015, the PSLO also launched a web-based mapping program and public tree database that allows people to monitor street trees, street lights, and related street furniture (Taipei City, 2015).

Taipei has formal tree management guidelines based on biological characteristics and site context (Hsu, 2010). This is important in a city with such a diversity of streetscape types (see Figure 4). In the downtown area, for example, sidewalks are often up to 8m (24 ft) wide and accommodate a range of uses including dedicated bike and pedestrian lanes, parking for mopeds, benches for sitting, bus stops, and single/double rows of trees and/or planting beds. Arterial streets often include landscaped medians planted with ground cover and trees while many of the sidewalks along local streets throughout the city are quite narrow, making tree planting difficult.



Fig. 4: Range of streetscape types in Taipei. Source: Top left, top right, and bottom left, Theodore S. Eisenman. Bottom right: Shenglin Chang.

Of note, these guidelines stipulate that any street wider than 8m should be planted with trees; but for sidewalks narrower than 2m, no new trees should be planted or replaced. Small planting beds are installed in sidewalks between 2.5–3m wide, and larger planting beds are installed in sidewalks wider than 3m. The guidelines also identify 39 species as the top choices for street tree planting. This list is based on 10 criteria: capacity to withstand air pollution; survival rate; air filtration capacity; attracting birds, butterflies, and other species; avoiding fallen fruits and leaves; avoiding pollen allergy; avoiding shallow and far-spreading root systems; strong and resilient branches to survive typhoons and severe winds; high pest tolerance and low risk for illness; providing shade. Some of the more common street trees in Taipei include Chinaberry or Indian bead tree (*Melia azedarach*), Toog tree or Bishop wood (*Bischofia javanica*), Camphor Tree (*Cinnamomum camphora*), Japanese bay tree (*Machilus thunbergia*), and Orchid Tree (*Bauhinia variegata*).

This planting list was updated in 2014, and it also includes six trees to be avoided for new planting and replacement due to a range of factors including shallow root systems, pollen allergenicity, dropping fruit, and fast-growing weak limbs. Of note, these trees were commonly planted during Japanese colonial rule and in the late-20th century thereafter, and include Banyan or Indian Laurel (*Ficus macrocarpa*); Sacred fig or Bodhi tree (*Ficus religiosa*); Rubber Tree (*Hevea brasiliensis*); Yellow Poinciana (*Peltophorum pterocarpum*); Cotton Tree (*Bombax ceiba*); Coral tree or Tiger's Claw (*Erythrina variegata*). Inclusion of *Ficus macrocarpa* is

particularly noteworthy, as this fast-growing tree is ubiquitous across Taipei due to widespread planting in the 1980s.

The aforementioned voluntary stewardship of street trees in Taipei also reflects a cultural affection for flora as well as a blurry line between the public and private realm. Trees in neighborhood parks, for example, are routinely adorned with orchids by local residents. Likewise, shop owners and residents commonly install containers with plants of various sizes in the adjacent sidewalk. These do-it-yourself sidewalk plantings can, however, create tension with neighbors, as well as the PSLO when street work needs to be conducted.

Citizen engagement in tree stewardship has also been advanced through a new nationwide tree planting proposal. Launched in 2019, the Patch by Planting (PBP) nonprofit group has identified places that can purportedly accommodate some 2.3 million new trees (PBP, 2020). This includes highway medians and circles, corporate and industrial campuses, and government-owned lands (e.g., landscapes dedicated to power lines, and idle land formerly dedicated to sugar cane production). In August 2020, the PBP was listed among five finalists in a national “hackathon” for sustainable development. With this finalist status, the Taiwanese central government is likely to promote the PBP project and support the public-private partnership.

Washington, D.C.

National Context

According to a nationwide survey spanning 667 municipalities in the United States, nearly two-thirds (64%) of cities assume legal responsibility for trees in the right-of-way (street trees between the sidewalk and curb or ally), with nearly one-third managed jointly (16%) or solely (16%) by adjacent property owners. But this differs by region: sole municipal responsibility is highest in the Northeast (79%) and Midwest (74%), while abutting property owners have greater responsibility for street trees in the South and West. In the West, for example, 46% of municipalities have sole responsibility for street trees while adjoining property owners have sole (28%) or joint (21%) responsibility (Hauer & Peterson, 2016). U.S. regions also have different histories related to municipal management of urban trees. In the Northeast, where some communities have had formally designated “tree wardens” since the early 1900s, (Ricard, 2005) municipalities have had a person responsible for public trees for some 50 years on average, while this has been the case for shorter periods in the Midwest (34 years), West (28 years), and South (22 years) (Hauer & Peterson, 2016).

Depending on location, municipal administration of public trees (of which streets and parks are principal sites) in the U.S. can be spread across several departments including public works, parks and recreation, streets/transportation, planning and community development, and urban forestry. However, parks and recreation, and public works departments were most common in 74% and 69%, respectively, of communities responding to the aforementioned survey. Of note, a designated forestry department is more common as population increases: 5% of municipalities with populations 2,500–4,999 have a forestry department whereas 46% of places with $\geq 50,000$ people have such a department. The size of municipalities was also found to be an important consideration in who manages urban trees and how administrative departments interact. In small towns, public administrators and public works directors commonly lead public tree management in addition to other activities, while people identified as arborists/foresters become more

common public tree managers as the size of the municipality increases. In small communities between 2,500– 9,999, 12% have a certified arborist whereas 83% of municipalities with at least 50,000 people have a certified arborist on staff.

Yet, the disciplinary identity and expertise of U.S. urban tree managers varies. According to two nationwide surveys, under half (45%–46%) of the people who manage urban trees identified themselves as arborists or urban foresters (Hauer & Peterson, 2016; O’Herrin et al., 2020) The others include a range of professionals commonly found in municipal government: public administrators (21%), horticulturalists (7%), outdoor recreationalists (6%), landscape architects (5%), urban planners (4%), foresters (3%), and civil engineers (2%). Of these, 80% are male and 90% are white (O’Herrin et al., 2020).

In addition to the distinctions noted above, there are differences in who manages mature trees versus new tree plantings in many U.S. communities. Nationwide, some two-thirds of municipalities involve volunteers in tree activity, and tree planting is by far the most common volunteer activity (85% of communities) followed by watering (40%), awareness/education programs (39%), tree pruning (28%), and fundraising (20%) (Hauer et al., 2018). This is especially true for tree planting campaigns which have become quite common in the United States (Campbell, 2017; Young, 2011), including the successful planting of one million trees in New York City between 2007–2016. These campaigns rely on a hybrid network of public, private, and nonprofit actors for financing, administration, and on-the-ground planting and stewardship. Importantly, non-technical volunteers are essential for planting and watering, and ensuring the survival of trees installed during such campaigns (Roman et al., 2015; Vogt et al., 2015). These greening initiatives can also trigger reorganization of urban forestry governance (Campbell, 2014). The state of Massachusetts, for example, launched a campaign in 2014 to plant tens of thousands of trees in 26 municipalities with below average household incomes and educational attainment. But this can create tension and lack of clear management authority between municipal and state administrators, resulting in many newly-planted trees not surviving (Breger et al., 2019).

As of 2014, U.S. municipalities had on average 76 trees per street mile, and municipal tree activities had a mean annual budget of \$801,595 per municipality, which works out to an average \$8.76 per capita and 0.52% of the total municipal budget. Of this, U.S. cities spent on average \$42.60 per street tree, although this was roughly double (\$82/street tree) in the South; cities also had on average 4,821 street trees per full-time employee (FTE), although the number of street trees per FTE increased in tandem with city population. The municipal general fund accounted for 72% of urban forestry financing, and over half (53%) of respondents thought this was adequate. Two-thirds of financing went to tree planting (14%), tree pruning (23%), tree removal (25%), or stump removal (4%). Importantly, expenditures on street trees accounted for the largest portion of municipal tree management budgets: 62% for street trees versus 23% for park trees (Hauer & Petersen, 2016).

Washington, D.C.

The U.S. capital city is affectionately referred to as the City of Trees (Choukas-Bradley & Alexander, 2008) (see Figure 5). So essential to the character of Washington, D.C. are trees, that they were an integral part of the city’s original design. In Pierre L’Enfant’s 1791 Plan, space in the public right-of-way was exclusively reserved for trees. The city’s sylvan moniker is also a

497 legacy of an 1870 Parking Act that characterized public right-of-ways as linear parks
498 (Government of the District of Columbia, 2019), and an 1872 planting campaign that yielded
499 60,000 new street trees while pushing the city to the brink of bankruptcy (DDOT, 2020c). Part of
500 a large-scale modernization effort to build sewage infrastructure and paved streets, this has been
501 described as the first city-wide tree planting of such magnitude in the United States, establishing
502 a precedent where some 280 miles of streets would be lined with trees by 1912 (Dümpelmann,
503 2019). This reflects a nationwide movement in the late 19th and early 20th century to green U.S.
504 cities through street tree planting and creation of large public parks (Eisenman, 2016b). Focusing
505 on the emergence of elm tree planting along streets first in New England and increasingly across
506 the nation, landscape historian Thomas Campanella has described this turn-of-the-century
507 greening as a democratic project and uniquely American aspiration to create the ‘pastoral city.’
508 (2003). This is echoed by another historian, Eric Rutkow, who describes “trees as one of the
509 great drivers of national development ... that helped to forge American identity” (2012, p. 314).

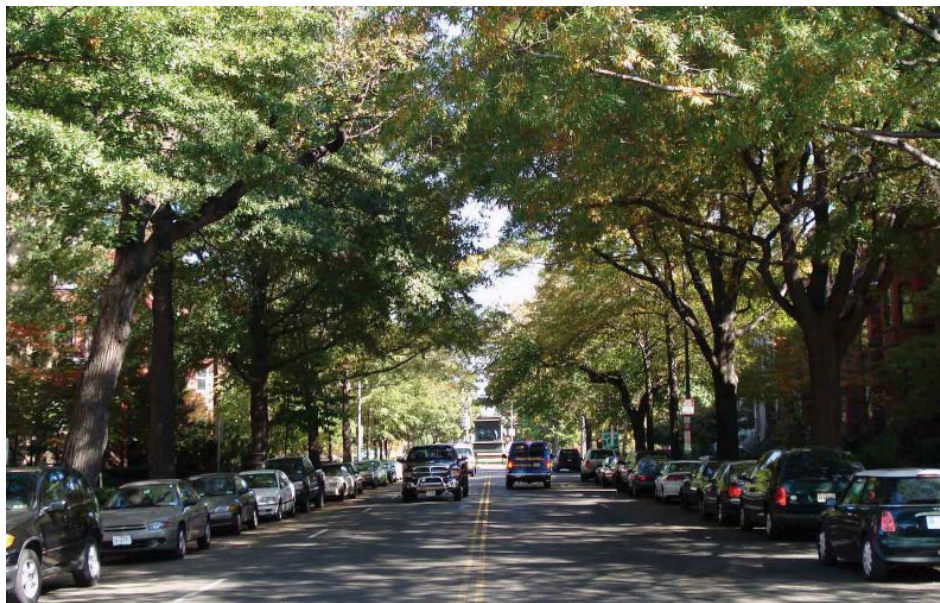


Fig. 5: Sylvan streetscape in Washington, D.C. Source: Government of the District of Columbia 2019.

513 Building upon this tradition and situating trees as important elements in a new sustainability
514 plan, the city established in 2011 a goal to plant 8,600 trees per year and achieve 40% urban tree
515 canopy (UTC) cover by 2032(District of Columbia, 2011). At the time, this goal represented an
516 ambitious 5% increase in UTC, and the city is making substantial progress, with a 2020 UTC of
517 38%.(DDOT, 2020c) Street tree planting has played an important role in the drive towards this
518 40% goal, and today the streets of the nation’s capital are nearing 100% stocking level. In other
519 words, spaces adjacent to a street that can accommodate a tree, have a tree (Sanders, personal
520 communication, August 17, 2020). The city averages 7.3 trees per 100m of street, and these trees
521 are evenly distributed across local, collector, and arterial streets, which is not the case in some
522 other capital cities (Smart et al., 2020). Of the District’s more than 200,000 trees on publicly
523 managed land today, some 157,000 are street trees (Sanders, personal communication, August
524 17, 2020).

The following are some of the most common of these street trees: Red Maple (*Acer rubrum*), Willow Oak (*Quercus phellos*), Pin Oak (*Quercus palustris*), American elm (*Ulmus americana*), and Red Oak (*Quercus rubra*). But in recent years, UFD has diversified its street trees to some 125 species, including many that are half to a third the size of large shade trees such as maples and oaks, e.g., Serviceberry (*Amelanchier*), Sweetbay magnolia (*Magnolia virginiana*), Japanese apricot (*Prunus mume*), American hornbeam (*Carpinus caroliniana*), and Persian parrotia (*Parrotia persica*). This has been characterized as a fundamental shift in what constitutes an appropriate street tree in the 21st century (Higgins, 2020). In addition to diversifying the species pool and reducing pest risks associated with shade tree monocultures, small statured trees are less likely to damage electrical lines and property.

The municipality's Department of Transportation (DDOT) Urban Forestry Division (UFD) has sole responsibility for street trees, as well as trees in other public landscapes such as parks and schools. It is worth noting that the 1870 Parking Act which characterized public right-of-ways as linear parks is still largely in effect today. This requires property owners to maintain the "public parking" directly abutting their property while giving the property owner the exclusive right to enter that public space (see Figure 6).

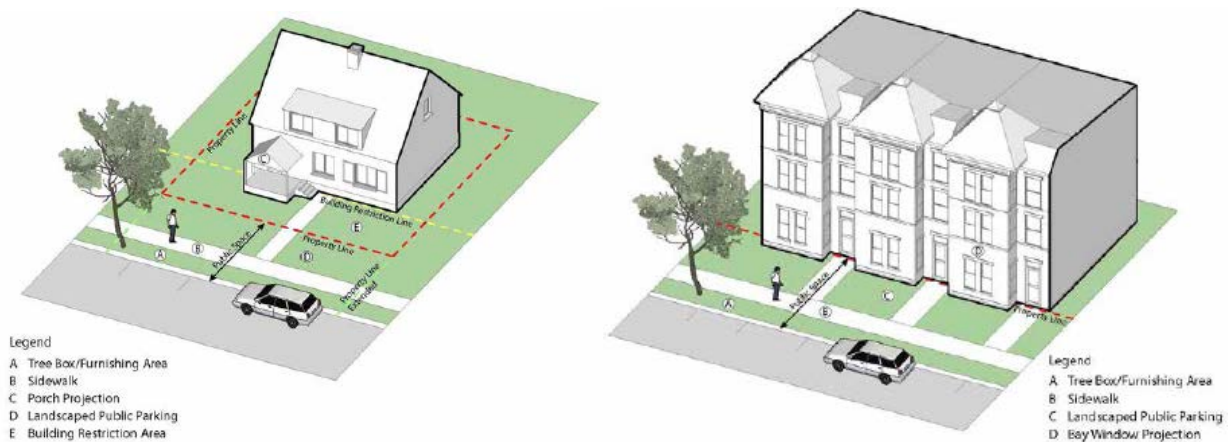


Fig. 6: Diagram depicting the landscaped “public parking” area adjacent to streets in Washington, D.C. Source: Government of the District of Columbia 2019.

DDOT UFD has over 20 full-time certified arborists on staff who do hands-on arboriculture but spend much of their time managing private contractors who do most of the technical work. This includes planting and stewarding some 8,000-8,500 street trees per year (DDOT, 2020b). The city does not rely upon volunteers to plant trees, however, when new street trees are planted in front of homes, the UFD notifies the homeowner and provides recommendations for watering the tree, if they so choose. The department has even created a web-based software application that allows homeowners to report when they have watered a tree, and to record information about the health of the tree (DDOT, 2020a).

To support tree planting, the city created a Tree Fund in 2002 (amended in 2016) that draws upon several sources beyond traditional financing from the municipal general fund. The city levies a fee for removing non-hazardous trees (usually due to building construction and development); and starting in 2011 these tree loss mitigation funds have directly supported street tree planting. Other financing includes grants from the city's Department of Energy and Environment, as well as the federal Clean Water Revolving Fund, both of which support the conservation or creation of vegetated green infrastructure systems to manage stormwater and protect the quality of local surface waters. All of these funds have allowed DDOT-UFD to increase street planting from 4,000 locations annually to some 8,000 over the past few years (DDOT, 2020d).

However, this has not occurred without challenges. In low-income, underserved communities there can be resistance to tree planting initiatives. Local residents have communicated concerns that tree pollen aggravates allergies, shade draws drug dealers, leaves clutter the landscape and are difficult to rake, and that it is unclear who will manage the trees. Some have also complained that greening attracts affluent gentrifiers and higher taxes, pushing out older residents (Gowen & Mellnik, 2013).

In addition to substantial public sector investment in street trees through the city's DDOT UFD, Washington, D.C. also has other private and nonprofit partners that engage in tree planting and stewardship in parks and on private lands that are not managed by DDOT. Most prominent is nonprofit organization Casey Trees, established in 2002 through a charitable donation by Betty Brown Casey who inherited \$50 to \$100 million upon the death of her husband, Eugene B. Casey, who accrued a fortune through real estate development across the District's metropolitan region (Jennings, 1994). Casey Trees has grown into a major urban forestry actor in the city, with roughly 55 full-time staff including 10 certified arborists and others who engage in fundraising, planning, policy, outreach, and education. The nonprofit organization plants 3,000-5,000 trees per year and since its inception has engaged thousands of citizen volunteers in tree planting and care. These volunteers account for up to 50% of the organization's historical planting, and to support this work the group has a range of engagement models, including a Corps of over 500 who have received training in tree planting, inventorying, and advocacy; some 2,500 citizen science volunteers; 55 certified tree advocates; and about 100 volunteers who routinely engage in tree planting.

Discussion

Several noteworthy themes emerge from the aforementioned cases. Each of the cities, for example, has a unique history. The settlement of Paris extends back some two millennia, and early examples of tree-lined streets include 17th century allées planted on behalf of kings, emperors, and the aristocracy. The underlying urban form of Washington, D.C., by contrast, is heavily informed by the L'Enfant plan of 1791 (Kostof, 1991), and citywide street tree planting a century later can be seen as a democratic project guided by an aesthetic aspiration for pastoral urbanism. Street tree planting in Taiwan, by extension, was heavily influenced by Japanese colonial rule 1895-1945. Such divergent histories reinforce the need to understand the historical legacies that undergird the structure and composition of contemporary urban forests (Roman et al., 2018).

Trees are some of the most potent and visible symbols of social process and collective identity (Rival, 1998), and this is especially poignant when considering trees along streets, which are the most commonly used public spaces of cities (Jacobs, 1993). In Taipei, *feng shui* design principles—dating back 3,000 years (Marafa, 2003; Xu, 1997)—still hold cultural significance today and can inhibit the siting of trees in front of doorways. In Paris, the role of trees as place-making elements in urban design seems to be shifting to a more ecological orientation that foregrounds biodiversity and ecosystem functions such as cooling. Ancillary effects of this shift may include diversification of tree species, reduction in aggressive pruning practices, and a more rustic landscape aesthetic (O’Sullivan, 2019b). Washington, D.C. has also diversified its palette to include some 125 street tree species, and it is noteworthy that many of these include smaller trees than typical shade trees. One potential outcome of this is reduced damage to infrastructure and property, which is an important—but often downplayed—risk of large trees (Roman et al., 2020).

Both Paris and Washington, D.C. have formal goals to increase canopy cover by 2030, and these cities are also pursuing efforts to diversify the types of trees planted along streets and in urban landscapes. This is a laudable goal that may reduce the likelihood of pests wiping out populations of tree monocultures while also supporting more diverse wildlife. But efforts to diversify street tree species would do well to consider insights derived from landscape preference research, which shows amongst other things that people desire a certain degree of visual order and ‘cues to care’ (Nassauer, 1995). This can, in turn, affect people’s stewardship practices, perceptions of safety, and social cohesion (Nassauer, 2011; Nassauer & Raskin, 2014) as well as the coherence and legibility of streetscapes (Jacobs, 1993; Massengale & Dover, 2014). As greening efforts expand the quantity and diversity of plant material along urban streets, the work of Peter Trowbridge and Nina Bassuk offers valuable guidance. In *Trees in the Urban Landscape*, the coauthors provide 16 groups of biologically diverse yet visually compatible trees (Trowbridge & Bassuk, 2004).

Another noteworthy theme that emerges from the cases described above, is that all three cities have unique approaches to the governance and stewardship of streetscape vegetation. Paris has several initiatives that allow or actively encourage citizens to plant low-growing plant material in sidewalks; a less formal but culturally accepted norm also exists in Taipei, where it is common for shop owners and residents to install numerous planters on adjacent sidewalks. This type of resident-led streetscape greening does not seem to be as prevalent in Washington, D.C., yet the city’s municipal regulation requires property owners to maintain the “public parking” directly abutting their property. The District also has a formal process, including a robust website, that encourages residents to water newly-planted trees and to record this activity. Paris also has a well-developed website that publicly tracks the health and management of the city’s street trees. Reflecting yet another form of decentralized governance, streetscape stewardship in Taipei draws upon a network of 456 neighborhood groups called *li*, who often adopt trees and become de facto stewards. The Taiwanese capital also tags its street trees, which provides not only a formal recording mechanism for municipal staff, it also communicates to the public that the trees are actively cared for.

Of the three cities, Washington, D.C. may have the most diverse funding approach dedicated to new tree planting. In addition to traditional financing from the municipal general fund, the city levies fees for removing non-hazardous trees and it has grants via municipal departments focused on energy, environment, and water that support street tree planting. The District also has a major nongovernmental partner that focuses on parks and private lands that are not managed by the city, and while this group does not plant street trees in Washington, D.C., it nevertheless reflects the prominent role of local nonprofit actors in urban tree planting nationwide, much of which focuses on streets (Eisenman et al., 2021).

An overarching theme that emerges from this study is that street tree planting and management figures prominently in each of the respective cities. All three municipalities show a net increase in the number of street trees in recent years, and there is substantial interest in the role that street trees can play in creating more livable and sustainable cities. This is good news, as streets represent one of—if not the most—common types of outdoor space that people engage on a regular basis. By extension, vegetated ‘travelscapes’ represent an excellent opportunity to provide an increasingly urbanized human population with the benefits of nature contact. This will, however, require ongoing investment in the social infrastructure that stewards green infrastructure, and a commitment to the experiential dimension of street trees, as streets are the backbone of the urban public realm.

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