Landscape and Urban Planning 248 (2024) 105102

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Managing urban trees through storms in three United States cities

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HIGHLIGHTS

- Studied urban forestry professionals' experiences and perceptions of storm management.
- There are barriers that encourage reactive rather than proactive actions.
- Challenges like aging infrastructure and differing agency goals are common.
- Varied perceptions exist about the characteristics of vulnerable communities to storms.
- Collaborative storm response was more common than collaborative storm preparation.

ARTICLE INFO

Keywords:
Urban forests
Vulnerability
Collaboration
Risk perception
Conflict

ABSTRACT

The benefits and functions of urban trees are well-studied, and stewardship groups, non-governmental organizations, tree professionals, and municipal leaders aim to increase canopy cover and expand planting programs. However, urban trees also present variable risks to human safety and infrastructure based on tree species, size, age, health, and maintenance history. Furthermore, changing global climate conditions and increased storm frequency and intensity make it imperative for urban forestry professionals to mitigate risk and collaborate with stakeholders. In this qualitative study, we provide insights about urban forestry professionals' (1) perceptions related to risk, management, and storm impacts, (2) preparation for and response to storms, (3) perceptions about community vulnerability and working with the public, and (4) perceptions about collaboration and conflict during storm management. Seventeen semi-structured interviews were conducted with urban tree professionals working with municipalities, managers of non-profit or volunteer-based groups, utility managers, and emergency managers from three cities in the United States: Jacksonville, Philadelphia, and Minneapolis. Across these cities, managers described direct and indirect ways that storms influenced tree planting, species selection, and removals while acknowledging aging infrastructure, limited resources, and multi-stakeholder coordination as recurring challenges. Results show that socio-demographic factors, neighborhood characteristics, historical legacies, and urban tree and canopy conditions increased perceived risk from trees during storms. Overall, participants agreed that collaboration across organizations and scales of management contributed positively to tree management in the context of storm events and the need for more collaboration among managers and with the public on storm preparation activities.

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https://doi.org/10.1016/j.landurbplan.2024.105102
Received 12 September 2023; Received in revised form 13 April 2024; Accepted 24 April 2024

1. Introduction

Urban forests encompass all the rows of individual street trees, clusters of trees found in parks and green belts, forest patches on private and public lands, and single trees around homes (Konijnendijk, Ricard, Kenney, & Randrup, 2006; Miller, Hauer, & Werner, 2015). Human behaviors and decisions influence the functioning of urban forests through tree-species selection, planting, maintenance, and removals (Hilbert et al., 2023; Roman, Fristensky, Lundgren, Cerwinka, & Lubar, 2022). Urban trees provide numerous ecosystem services, including providing shade and mitigating urban heat islands, reducing stormwater runoff, supporting wildlife habitats, and providing spaces for people to exercise, socialize and interact with nature (Livesley, Mcpherson, & Calfapietra, 2016; Pregitzer et al., 2019). Although urban trees also help with carbon sequestration, the evidence on its potential is limited (Pataki et al., 2021). These benefits underpin the growth of urban tree-planting campaigns worldwide (Eisenman, Flanders, Harper, Hauer, & Lieberknecht, 2021; Lobe Ekamby & Mudu, 2022; Sousa-Silva, Duflos, Barona, & Paquette, 2023).

Although urban trees are generally considered beneficial (Lyytimäki and Sipilä, 2009; Miller, Hauer, & Werner, 2015), growing literature supports a more holistic understanding, including recognition of ecosystem disservices (Roman et al., 2021; Pataki et al., 2021; Eisenman et al., 2019). Ecosystem disservices are "the ecosystem generated functions, processes and attributes that result in perceived or actual negative impacts on human well-being" (Shackleton et al., 2016). For urban trees, these disservices include (1) damages to, and conflicts with, infrastructure, including storm-related concerns, traffic obstruction, and property and utility damage, (2) health and safety concerns, such as the risk of injury from branch or tree failure, perceived threats, and the production of allergens, (3) social, cultural, and aesthetic issues including nuisance and litter, (4) green gentrification, and (5) negative environmental impacts, including greenhouse gas emissions from tree production and care, as well as irrigation in arid cities (Roman et al., 2021).

When examining how communities interact with urban forests, it is essential to consider ecosystem disservices (Lyytimäki and Sipilä, 2009). Furthermore, ecosystem disservices of urban trees are costly for municipalities and private landowners, especially after storm events, due to costs associated with debris and litter removal (Escobedo, Luley, Bond, Staudhammer, & Bartel, 2009), liability, and because downed trees may damage built infrastructure (Conway & Yip, 2016). For example, after Hurricane Ida (2021), infrastructure damages and response activities cost 31 million USD in Philadelphia, Pennsylvania (Reyes, 2021). Despite increasing research about the ecosystem services and disservices of urban trees, more research is needed to assess how specific ecosystem disservices are perceived and managed by professionals and the non-expert public (Roman et al., 2021). This is especially timely as extreme weather events are predicted to increase in frequency and severity (Camelo, Mayo, & Gutmann, 2020), thereby increasing threats to urban ecosystems and communities. Storm effects like more intense and frequent rainfall are projected to increase, especially in the northeastern U.S. (U.S. Global Change Research Program, 2017). Storm impacts are especially problematic because they often coincide with aging infrastructure (Panteli & Mancarella, 2015), rapid urbanization, and high population density in vulnerable areas (Fussell et al., 2017).

Urban forest management is complex, involving diverse actors, expectations, and management priorities (Vogt, 2020), including both public and private entities (Miller, Hauer, & Werner, 2015). The diversity of people involved in urban tree management – including but not limited to municipal managers, arborists, developers, utility workers, landscape planners, non-governmental organizations, and residents – can lead to conflicts over tree decisions and management priorities. For example, some urban forestry professionals value trees for a range of environmental, human health and well-being, and wildlife benefits while others hold strong emotional attachments to trees, leading to conflicts over the tree species' selection, use, function, and socio-ecological role in urban settings (Kirkpatrick, Davison, & Harwood, 2013). Perceptions also play a crucial role in people's understanding of the services or disservices of trees (Roman et al., 2021) and subsequent tree management related to storm risk.

The purpose of this research is to assess how urban forestry professionals perceive the relationship between trees and storm events in their cities, specifically perceptions about: (1) risk, management, and storm impacts, (2) preparation for and response to storms, (3) community vulnerability and working with the public, and (4) collaboration and conflict. We addressed these objectives through interviews with urban forestry professionals in three U.S. cities: Jacksonville, Florida; Philadelphia, Pennsylvania; and Minneapolis, Minnesota, representing a range of urban and climatic contexts.

2. Background on urban tree management, risk assessments, and collaboration

Urban forest management can be proactive or reactive. Proactive urban forest management incorporates planning, systematic processes, and preventative action through *precautionary* tree care practices, including anticipating tree disservices and threats to trees while supporting and sustaining tree-related services. On the other hand, reactive management *responds* to an unplanned event or crisis aimed at mitigating threats or hazards after they occur (Healy et al., 2023). Using tree inventories and strategic plans, urban forestry professionals can set priorities and work towards measurable goals that reduce the negative impacts of unplanned events. For instance, planting the 'right tree' in the 'right place' (appropriately matching the tree species to the planting site and conditions) can affect the tree's establishment and maintenance and reduce future tree-infrastructure conflicts (Vogt, Hauer, & Fischer, 2015; Roman et al., 2021). Proactive management activities often involve inspections and actions to reduce risk, including pruning and removal (Klein, Koeser, Hauer, Hansen, & Escobedo, 2019; Roman et al., 2021). In urban forest management, discussions about risks, including risk assessments, are critical because managers must make decisions despite uncertainties and changing weather patterns (Eiser et al., 2012).

A review of tree risk assessment literature defines risk as the probability and severity of an unwanted or harmful event occurring within a specific time interval (Klein et al., 2019). There has been a rapid increase in research on tree risk in the last 20–30 years (Koeser, Hauer, Miesbauer, & Peterson, 2016). Professional organizations like the International Society of Arboriculture (ISA) provide information and training on tree risk assessments, such as Tree Risk Assessment Qualification (TRAQ) – a specialized training program to standardize the inspection process and minimize biases in tree risk assessments. Nonetheless, assessed risk levels still tend to vary among professionals (Klein et al., 2019). Though some tree risk assessment methods involve quantitative evaluations (Ellison, 2005), most characterize the likelihood of impact, the likelihood of failure, and consequences of a tree failure qualitatively based on the judgment of individual assessors (Klein et al., 2019). As such, assessments about the likelihood of impact and target occupancy (how often people, property, or activities occupy a space which could be impacted by a tree failure), can be subjective (Klein, Koeser, Hauer, Hansen, & Escobedo, 2016). Individual assessors' perceptions about tree risk ultimately play a prominent role in management decision-making, and these perceptions are often influenced by the assessors' personal experiences, backgrounds, and biases (Klein et al., 2019).

Risk perceptions and tolerance levels are socially constructed and shaped by social-ecological, personal, and historical experiences and cultural contexts. Socio-demographic factors like age, gender, race, and child rearing may also influence risk perceptions (Harlan, Sarango, Mack, & Stephens, 2019; Peacock, Brody, & Highfield, 2005; Koeser & Smiley, 2017). Additionally, the wide range of professionals' experiences, knowledge, and backgrounds adds to variability in tree risk assessments (Klein et al., 2020). Because assessors view risk through contextual lenses, personal bias can influence risk assessment and management (Klein et al., 2020; Koeser & Smiley, 2017). If a group shares a bias, it can lead to artificial precision (Klein et al., 2019). On an individual level, artificial precision may be compounded by personal beliefs, values, and lived experiences, which impact personal biases or a person's 'positionality' (Takacs, 2003). In risk assessment, personal bias can also be shaped by a lack of available data and reliance on intuition (Slovic, 1987). Missing information or uncertainty in tree-related risk stems from the limited capacity to predict storms, storm effects, progression of natural processes, occupancy levels near trees, and consequences of tree failure. Inherently, all large trees located in the vicinity of built structures, vehicular traffic, and pedestrians carry some level of risk (Smiley, Matheny, & Lilly, 2017). However, risk assessments can better inform actions to ensure that any unnecessary loss of tree benefits can be avoided resulting from unnecessary risk mitigation actions (Klein et al., 2020).

Consequences of tree failure in urban areas range from minor (e.g., light damage to a fence) to severe (e.g. powerline failure, building and vehicle damage, injury, hospitalization, and death, although loss of human life from tree failure is rare) (Smiley et al., 2017; Koeser et al., 2020). Owing to the fiscal and legal repercussions of urban tree failures, risk assessments and management may vary depending on socioeconomic context. For publicly owned or managed urban trees, cities are sometimes found legally responsible for property damage or personal injury. The risk of tree failure and consequent liability plays a significant role in tree risk assessment because cities with previous liability claims are more likely to perform tree risk management activities (Koeser et al., 2016). Cities and towns across the U.S. are also more likely to manage tree risks if they have certified arborists on staff, strategic plans, updated tree inventories, and/or collected risk data (Koeser et al., 2016). Although these factors impact risk assessments and management, there is limited research examining the influence of storms on urban tree risk assessments in cities (Koeser et al., 2020).

As a shared resource, urban forests are often collaboratively managed in complex governance arrangements, which has ramifications in managing trees for storms. Collaboration involves diverse, independent stakeholders working together, building relationships, and interacting to build consensus and achieve specific goals (Margerum, 2011). However, given the complexity of urban forest management, the diversity of stakeholders involved presents various conflicts that can influence priorities, management, maintenance, and use of urban forests. Information sharing is a common challenge for stakeholder collaboration, and there is sometimes a need for a mediating organization to develop standard communication tools that can be used by diverse groups (Ugolini et al., 2015). For instance, a study of European urban forestry and green infrastructure professionals found that professional organizations such as ISA were vital for providing training and facilitating relationship-building between stakeholders that encourages collaboration (Ugolini et al., 2015). As storms become more frequent, such collaboration among stakeholders becomes more important.

3. Methods

To examine tree management related to storms, we conducted one-on-one semi-structured interviews with urban forestry professionals in three U.S. cities: Jacksonville, Florida; Philadelphia, Pennsylvania; and Minneapolis, Minnesota. These case study cities were selected based on relative population size, the existence of municipal forestry programs, and experience with hazardous storm events that impacted urban tree management and planning, such as extreme thunderstorms, hurricanes, tropical storms, snowstorms, and ice storms (Table 1). These cities were also included because the members of the research team were knowledgeable about urban forest management in those cities and were able to leverage their professional networks to identify key informants in these cities. We used semi-structured interviews because this method gives the interviewer some structure and flexibility to elicit responses while allowing participants to express their lived experiences, perspectives, emotions, and interpretations of events in their unique ways (Adeoye-Olatunde & Olenik, 2021).

We used purposive sampling (Guest, Bunce, & Johnson, 2006) to recruit interviewees based on their professional role or title in urban forestry. Specifically, we recruited participants from the following categories: utility managers, municipal managers, emergency managers,

Table 1
Overview of three case cities.

	Jacksonville	Philadelphia	Minneapolis
Population (2022)	949,611[a]	1,603,797[b]	429,954[c]
Tree canopy cover	41 %[d]	20 %[e]	29.8 %[f]
Does this city have an urban forest management plan or policy?	In the process of developing a plan[g]	Yes- Philly Tree Plan (2023)[h]	Yes- The Minneapolis Urban Forest Policy (2016)[i]
Most common tree species	*Lagerstroemia indica, Quercus virginiana, Sabal palmetto*[j]	*Platanus x hispanica, Prunus* sp.*, Acer platanoides, Acer rubrum*[k]	*Fraxinus pennsylvanica, Acer saccharum, Acer platanoides* L.*, Tilia cordata, Ulmus americana*[l]
Typical Storm Types	Thunderstorms; tropical storms; hurricanes; tornadoes; windstorms	Thunderstorms; tropical storms; hurricanes; tornadoes; windstorms; snowstorms; ice storms	Thunderstorms; remnants of tropical storms; tornadoes; windstorms; snowstorms; ice storms

[a] U.S. Census Bureau. 2022. Population Estimates, July 1, 2022 (V2022) – Jacksonville, FL [data table]. *Quick Facts*. Retrieved from https://www.census.gov/quickfacts/jacksonvillecityflorida.

[b] U.S. Census Bureau. 2022. Population Estimates, July 1, 2022 (V2022) – Philadelphia, PA [data table]. *Quick Facts*. Retrieved from https://www.census.gov/quickfacts/philadelphiacitypennsylvania.

[c] U.S. Census Bureau. 2022. Population Estimates, July 1, 2022 (V2022) – Minneapolis, MN [data table]. *Quick Facts*. Retrieved from https://www.census.gov/quickfacts/minneapoliscityminnesota.

[d] Plan-it Geo, LLC. 2017. An Assessment of Urban Tree Canopy in the City of Jacksonville, Florida [PDF file]. Retrieved from https://www.coj.net/departments/neighborhoods/environmental-quality/docs/jacksonville-urban-tree-canopy-report.aspx.

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[f] The Urban Canopy. n.d. Minneapolis Parks and Recreation Board. https://www.minneapolisparks.org/park-care-improvements/trees/.

[g] Urban-Forest-MP-Minutes-03-16-2023. (n.d.). https://www.jacksonville.gov/getattachment/Departments/Public-Works/Tree-Commission/Urban-Forest-MP-Minutes-03-16-2023.pdf.

[h] Philly Tree Plan Growing Our Urban Forest. (n.d.). Retrieved November 15, 2023, from https://www.phila.gov/media/20230223005617/Philly-Tree-Plan.pdf.

[i] 2016-01239 - Urban Forestry Policy Update. (n.d.). Retrieved November 15, 2023, from https://lims.minneapolismn.gov/file/2016-01239.

[j] ArborPro, Inc. (2019). Jacksonville 2019 I-Tree Inventory Final. Retrieved from https://www.jacksonville.gov/getattachment/Departments/Public-Works/Urban-Forestry/Education/Jacksonville-2019-I-Tree-Inventory-Final.pdf.aspx?lang=en-US.

[k] Bigelow Jr, L. M., Fahey, R. T., Grabosky, J., Hallett, R. A., Henning, J. G., Johnson, M. L., & Roman, L. A. (2024). Predictors of street tree survival in Philadelphia: tree traits, biophysical environment, and socioeconomic context. *Urban Forestry & Urban Greening*, 128284.

[l] McPherson, E.G., Simpson, J. R., Peper, P. J., Maco, S. E., Gardner, S. L., Cozad, S. K., ... & Herman, J. (2005). City of Minneapolis, Minnesota municipal tree resource analysis. Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station.

and managers of non-profit or volunteer-based groups. Although we met those quotas in Jacksonville and Philadelphia, we encountered challenges recruiting for all categories in Minneapolis. We also used snowball sampling to find additional participants for each category (Bernard, 2011). Invitation emails were sent to thirty-four participants, followed by two reminder emails, as needed. Of the thirty-four invitees, we were able to successfully schedule interviews with seventeen professionals: Jacksonville (6), Minneapolis (3), Philadelphia (8). The data collection period coincided with the COVID-19 pandemic, delaying some interviews. There were additional challenges with participant recruitment, including lack of availability, non-response, limited sample size, and low capacity of urban forestry departments.

Interviews were conducted individually on Zoom virtual meeting software from August 2021 to August 2022 (Communications, 2022) and lasted 35 – 60 min. They were recorded and transcribed using Zoom's automated transcription feature. Individual transcriptions and recordings were then reviewed and corrected as needed. The number of interviewees varied based on participants' availability and size of the urban forestry departments. We concluded the data collection after 17 interviews and almost a year of soliciting participation. The semi-structured interview protocol included open-ended questions about (1) general information about the interviewee background, (2) risk perceptions of urban trees and storm events, (3) liability and working with the public, and (4) collaboration. The same questions were asked of each participant.

The cleaned transcriptions were uploaded to NVivo 12 Plus software for analysis (Lumivero, 2023). The data were analyzed with thematic analysis involving deductive and inductive codes (Bernard, 2011). Deductive coding refers to codes developed from the interview protocol, while inductive codes emerged from the interview responses. Thematic content analysis was conducted by beginning an initial set of codes from the interview questions (deductive codes). We then reviewed the transcripts of each interview for themes not originally captured by codes, but which repeated across several cases or stood out as unique among cases (inductive codes). Codes were then analyzed and grouped into larger themes. We did an intercoder reliability test between two individual coders (90 % agreement) to minimize bias. The interview protocol was reviewed and approved by the University of Florida's Institutional Review Board (IRB#: IRB202101044).

4. Results

All 17 interviewees were in leadership, supervisory, or managerial roles. Participants worked in various settings, including street trees and rights-of-way, public parks or other public spaces, residential areas, institutional properties, and forest patches or fragments. Experience working with urban trees ranged from 1.5 to 40 years. In alignment with our interview questions, we organized the results into broad themes related to (1) urban tree management and perceptions of storm impacts, (2) preparation, standards of risk and response to storms, (3) perceptions of community vulnerability and working with the public and, (4) collaboration and conflicts.

4.1. Internal and external challenges to urban tree management and storm severity

Urban forestry professionals had varying perceptions about what made a storm severe. Interviewees classified storms as severe if they: had long recovery or response times, needed to activate additional support crews, or collaborate with response teams in other cities. Rain and flooding were the most frequently discussed impacts by participants in Philadelphia (8), Jacksonville (5), and Minneapolis (1). Specifically, named storms were mentioned by participants in Philadelphia (2) and Jacksonville (6), and storms with major winds were described as significant or impactful in only Philadelphia (2) and Minneapolis (3). Storm recurrence, unpredictability, and severity could lead to compound effects such as flooded soil, leaning trees, and broken branches. Additionally, seven interviewees highlighted how storms impacted the structural integrity of trees through high winds or heavy snow loading. Overall, interviewees called attention to several challenges related to urban tree management and storms, including internal concerns about staff, capacity and funding, and external challenges such as infrastructure and changing climates.

4.1.1. Internal challenges to urban tree management and storm severity

Seven interviewees explained that although significant storm events like hurricanes or derechos (rapidly moving bands of thunderstorms and strong winds) may be infrequent discrete events, recovery and response times are lengthy and can impact job responsibilities. Eight interviewees including municipal and utility interviewees in Jacksonville (3) and Philadelphia (1) described severe storms as disruptive to regular work schedules, workflow, and duties. One interviewee explained:

> *"We have less than 30 staff who do in-house clean-up work. We have ten staff in our street tree division, and that's where the inspectors are, so whenever there's storm-related or emergency-related work, those inspectors have to stop their regular work and go out and do the emergency inspection to direct the work. And then, if there is emergency-related clean-up, again, our crews have to stop their regular workflow and go do that."*

Seven interviewees highlighted that severe storms have impacts beyond their respective city boundaries. For example, an interviewee in Jacksonville recalls that although Hurricanes Matthew and Irma did not directly impact Jacksonville, the hurricanes' impact in two neighboring states affected Jacksonville's urban forest management operations because of mutual aid and staff redirected to assist in recovery, consequently impacting workflow by temporarily reducing staff capacity.

4.1.2. External challenges to urban tree management and storm severity

Seven interviewees highlighted that storm response is complicated by external factors that are difficult, if not impossible, to address, including urban morphology and traffic flow. An interviewee explained:

> *"Jacksonville is separated by the St. Johns River, so we do have a logistical challenge of getting over bridges if the storm hits on each side of the river. How do we get our crews from place to place? So, some of the things that are kind of interesting that when these storms hit, they did not only take out utilities, they also block roads. And fire, police, emergency rescue can't get where they need to be…"*

Across all three cities, urban forestry professionals described broader challenges in storm-related forest management and decision-making, including complex issues like aging infrastructure, lack of access to work sites, differing agency goals, and perceptions about the public fear of trees. Nine interviewees emphasized the need to think differently about long-term urban tree planning and changing climates.

4.2. Standards of risk, preparation and response to storm events

Interviewees gave mixed responses about tree risk assessments; some relied on TRAQ definitions while others incorporated other professional judgments. Overall, utility managers primarily described maintaining standards for defining risk and emphasized the importance of professional certifications when determining risk. For example, in Philadelphia, a utility manager described how their team followed the TRAQ guidelines in its tree risk assessments:

> *"… we look at, you know, the likelihood of failure, likelihood of impact, and then the consequences of the failure and impact on our facilities as our way of determining our risk ranking. …when they're out looking at areas where we're going to be doing work, you know, they use that ranking, and that's how we help prioritize which trees we're going to address."*

In Jacksonville, certified arborists and foresters were prioritized in the hiring process as this official certification enabled staff to effectively assess tree defects and potential failure in preparation for storms. Although Jacksonville did not have a written standard for storm preparedness, all their municipal team members were TRAQ certified. On the other hand, while some municipal managers in Philadelphia had TRAQ training, it was only sometimes incorporated into regular tree work. In Philadelphia risk determination was based on individual assessments, and some degree of individual subjectivity was acknowledged. For instance, one interviewee said that risk determination was *"… just the judgment of the inspector or the arborist whose role it is to make that decision"*. Decisions about tree risk are context-specific, while decisions about tree emergencies were handled by inspectors in the street tree office, some of whom were certified arborists. While professional qualifications were not absent in Philadelphia, (except for utility managers) responses indicated that these qualifications were less emphasized in shaping perceptions of risk. Across all cases, the emergency managers we interviewed deferred tree risk evaluations to urban forestry departments in their respective cities. None of the nonprofit and volunteer-based group interviewees explicitly used tree risk standards and were largely hands-off during storm response.

4.2.1. *Storm response*

Overall, storm response in cities depended on the amount of damage, staff availability, time of storm occurrence, and procedures in place. Collaboration was central to response processes in each city (Table 2). Six interviewees described how work crews would remain on standby during storms allowing them to respond as soon as wind intensity was reduced to a safe operating level. Meanwhile, calls to respond to downed or hazardous trees are monitored. Across all interviewees, response and clean-up actions prioritized public safety. In addition to prioritizing public safety by cleaning up hazardous trees and debris after the storms, five interviewees also highlighted the importance of selecting and planting replacement trees lost in storm events.

Table 2
Interviewee responses to how organizations prepare and respond to storm events.

Interviewee role	"How does your organization **prepare for storms**?"	"How does your organization **respond to storms**?"
Utility manager (n = 3)	• Have and follow a plan or process Pruning cycles Call-in and prepare additional on-call crews Initiate operations control center meetings	• Coordinate multi-organization command systems Concentrate activity in areas of public safety concern and heavy damage Ready emergency response team
Municipal manager (n = 8)	• Remove hazardous trees Perform basic tree maintenance Organize employees and equipment Call-in external crews and prepare contractors Understand the chain of command and follow internal workflow	• Call for mutual aid if needed Perform phased clean-up Inspect emergencies Enter triage mode to assess damage Clear roads of hazards and for access
Emergency response manager (n = 2)	• Develop a city plan Meet and communicate with collaborating agencies Organize severe weather workshop	• Activate collaboration team Enter triage mode to assess damage Prioritize safety and utility wires Communicate with partners to address emergency calls Evaluate response actions for future improvements
Non-profit and tree advocacy staff (n = 4)	• Consider trees as green stormwater infrastructure Plant the "right tree in the right place" Provide public outreach and education about tree care	• Raise funds for resilient home repairs Replace trees lost to storms Call partners as needed

4.2.2. *Storm preparation*

Although storm preparation varies in each city, there are some important commonalities (Table 2). Interviewees from all three cities noted that their institutions' storm preparation included storm preparedness plans, staff organization, protocols for removing hazardous trees and debris, activation of emergency teams, and collaboration with other city organizations/agencies. While all interviewees highlighted the importance of collaboration, interviewees had defined roles in storm preparedness and response in their respective cities. Members of non-profit and volunteer-based groups described their roles as proactive and prioritized building urban resilience including long-term climate solutions and mitigation efforts like establishing green infrastructure after a storm, primarily via increasing tree plantings.

Managers had varied perspectives about how storms impacted tree species selection and planting in their cities. Eight interviewees believed that storms directly impacted their decisions about tree species selection. On the other hand, four interviewees believed the impacts were more indirect, for example – a tree's resilience to withstand storm events. Interviewees also expressed concerns regarding tree diversity (5), aesthetics (2), litter control (1), tree hardiness and tolerance for urban conditions (8), native or non-invasive species (2), and tree size at maturity (10). Specifically, utility managers were concerned about flood-resistant trees and species that did not interfere with power lines (Table 2).

Discussions about planting the "right tree in the right place" emerged organically with several interviewees in Philadelphia (4) and Jacksonville (4) elaborating on what this saying meant to them. "Right tree in the right place" entails interviewees' considerations of historical storm impacts, site conditions and built infrastructure. For example, in Jacksonville, a utility manager and a nonprofit and volunteer-based group manager explained that they were now considering planting more flood-resistant trees in flood-prone areas because of previous storm impacts. In Jacksonville, another non-profit and volunteer-based group manager mentioned cypress (*Taxodium* sp.*)* trees as a good option for areas with standing water or retention ponds. Planting the "right tree in the right place" also meant considering space and size. For example, a municipal manager cited palm trees in Jacksonville as a good option in some medians or closer to riverfronts because their smaller root systems would minimize damage to roads and structural conflicts. In Philadelphia, a utility manager discussed their partnership with a local non-governmental organization advocating trees and educating the public about planting "the right tree in the right place." Four interviewees, including utility managers and non-profit or volunteer-based group managers in Philadelphia and Jacksonville explained that utility lines dictated the size of trees planted. One non-profit or volunteer-based group manager described, for instance, that they sometimes prefer to plant a smaller tree:

> I think that the utility company has probably, as a part of their mitigation requirements they are obligated to put in a certain size tree and a certain number of trees in their service area. We are not necessarily bound to that size requirement, and sometimes we would rather put in shrubs or, you know, very, very small trees

Some interviewees gave examples of problematic species in their cities – although only sometimes about storms. For example, in Philadelphia, three interviewees described London planetrees (*Platanus* × *hispanica*) as trees that historically may have been planted in smaller median strips. In Philadelphia, one interviewee avoided planting pears (*Pyrus* sp.), which were known to split or drop limbs when they accumulated ice and snow, while a non-profit and volunteer-based interviewee specified that tree's size, planting space, and age were among the more important factors in determining what made trees vulnerable to storms.

4.3. Perceptions of vulnerability and working with the public

Interviewees were asked about the vulnerability of urban populations related to storms and trees. Although responses varied across cities, interviewees described a spectrum of social and ecological contexts broadly based on socio-demographic features, neighborhood characteristics, historical legacy, and condition of the urban forest canopy (Table 3). In Jacksonville and Philadelphia, characteristics like aging trees, older neighborhoods, higher income, higher tree density, or large trees increased an area's vulnerability to storms. However, low-income areas, Communities of Color, and areas with fewer trees or larger and older trees were also recognized as vulnerable to storm impacts in urban areas (Table 3). Contradicting categorizations about what made an area vulnerable were explained by an emergency manager in Jacksonville as:

> *"I think it runs the gambit. We have areas of the city that are more impoverished and where, if you know there's a private tree on their property and there's a dead limb, they might not have the means to have someone come out and clear it, and that was a risk. You also have very wealthy riverfront properties that have these beautiful, historical oak trees, but again, those can cause a lot of damage, so I think, no matter where you are on the socio-economic scale, there are residents at risk on all levels from tree damage."*

Interviewees expressed various responses for how urban populations might be better served regarding storm events and urban tree management. In Jacksonville, interviewees recommended more educational programming for residents to better serve vulnerable populations. This type of educational programming can include providing more information to urban residents about urban tree care and storm preparedness.

Table 3
Interviewee responses to "Can you think of urban populations or neighborhoods that might be more impacted/vulnerable than others to storms as it relates to urban trees?"

Factors that contribute to an area's vulnerability to, and impacts from, storm events	
Socio-demographic factors	Communities of Color (2) Marginalized neighborhoods (2) Neighborhoods with older residents (1) High renter-occupied homes (2) Low-income areas (3) Wealthy areas (3)
Neighborhood characteristics	Flood prone areas (2) Limited resources (including financial) (3) Downtown areas (1) Aging infrastructure (4) Smaller properties (1)
Historical legacies	Redlined communities [1] (2) History of storm damage (2)
Condition of urban trees and canopy	Areas with large, old trees (4) Neighborhoods with high canopy coverage (2) Areas with stressed trees (2) Neighborhoods with low canopy coverage (2) Little tree diversity (2)

[1] Redlining was a form of housing discrimination in the early to mid-20th century in the U.S. See (Locke et al., 2021).

These populations may be vulnerable to the impacts of storms including the potential of property or infrastructure damage, or personal injuries and reduced capacity to recover based on historical legacies and socio-economic disadvantages. However, in Philadelphia, one utility manager described the need to *"reach out [and work] with the communities to really understand what their needs are instead of just imposing you know what we think would help."* Respondents in both Jacksonville and Philadelphia described past experiences in which vulnerable populations did not perceive their tree management work as 'helpful', or where the historical maintenance of trees has been unequal or underfunded. For example, one non-profit manager described issues with equity and maintenance:

> *"The squeaky wheel gets the grease, so the wealthier neighborhoods complain more and get things addressed more than the older neighborhoods and the black neighborhoods and also, I mean, historically those neighborhoods there were activists in them, and they were complaining, and they were trying to get things done, they were ignored…"*

This aforementioned interviewee recommended advocacy to better serve the vulnerable and poorer neighborhoods identified above while another interviewee described developing more green infrastructure for flood-prone areas, including bioswales and increasing canopy. This interviewee believed that aging infrastructure in older neighborhoods and low-lying areas were more vulnerable to the impacts of storms. Interviewees gave examples of aging infrastructure like older planting strips, which are too small for the species of tree planted in them, above-ground utility and wiring, large numbers of aging trees, and older drainage systems that can be overwhelmed by heavy rains and flooding. Seven interviewees explicitly mentioned trees as green infrastructure and one non-profit manager from Jacksonville acknowledged that green stormwater infrastructure (including vegetative features and permeable pavements) could lessen the impacts of storms in these areas.

However, one interviewee mentioned that it was challenging for them to think about ways to serve vulnerable populations better because their job responsibility focused primarily on trees. For this interviewee, improving response time and clearing downed trees to improve safety would best serve vulnerable populations. Sixteen interviewees had action-centered ideas about addressing vulnerability, including (1) proactive care for trees, including increased funding for maintenance and risk assessment, (2) moving quickly and redirecting resources acutely to respond to storm-affected areas, (3) putting policies and programs in place to make the city more resilient overall, (4) informing vulnerable populations about the risk, (5) increasing education about trees and tree care, including responding to residents in a "balanced" way, (6) introducing funding to assist private tree owners with tree care, and (7) planting the "right tree in the right place." Interviewees had differing perspectives about how to serve vulnerable populations, with non-profit and volunteer-based groups leaning towards greater public engagement and participation in general tree care.

4.4. Collaboration and conflicts

Among all cities, participants defined collaboration as (1) having shared or common goals, (2) building relationships, and (3) sharing resources. Overall, participants agreed that big-picture goals such as safety or increasing tree canopy were important. Nonprofit interviewees advocated for more trees and education and shared goals with other organizations. Interviewees described collaborating with diverse professionals in all storm preparedness and response phases.

Ten interviewees viewed collaboration with other agencies or organizations as a way to overcome barriers tied to limited resources (e.g., time, information, funding, staff, or equipment). An interviewee in Jacksonville described "core teams" as collaborative, established, and innovative and expressed pride in their city's emergency response coordination during and immediately after storms:

"…it will be a fire department rig; they'll have a member of the Jacksonville sheriff's office with them, someone from the energy utility, and members of the public works department all on one rig. They drive the city streets, see a downed tree, chop it up, and move it to the side [to clear the] downed power line. The guy that energy utilities have going up making sure it's turned off is there. And we are the first city in the country to have a program like this. Now it's pretty much standard practice and [in] a lot of other places…"

Collaboration could also be internal and multidirectional across departments or organizations and their communities. Manager communications primarily occurred in organized meetings, phone calls, or Interviewees emphasized that knowing who to call before a storm was crucial to effective response and collaboration. One professional described:

"… for instance, you might ask me, "What's the name of the municipal forester for the city…" I should be able to tell you that. … I should already have a relationship with him and communication, you know, maybe once a month, I can meet with him or just give me a quick call…So, communication and having that relationship is important, but we also have to be prepared to know where we could share resources."

Professionals build collaborative relationships based on trust and familiarity. Interviewees expressed knowing some people 'well' or not knowing them beyond their email signature. One interviewee described the benefits of maintaining established peer relationships:

"Well, we did have an instance … When that tornado hit, they did offer to come over and actually help do some tree work for us, which was very surprising because not only are they a separate city, but they're actually in a different county…. they do their own thing …but in that case, it was more just the relationship we had with the folks over there…. "

One interviewee also described the benefit of flexibility in their partnerships, especially when their goals did not align: *"There are times that we have different things we might want to do, but you know, then we just work with a different partner."* In one city, participants described storm-specific conflicts like inconsistent language or emergency codes in shared communications systems. For example, organizations used different priority rating systems to tackle emergency problems during storm response. While these challenges required cooperation from different groups, an interviewee explained:

"Everyone has their own perspective on things based on the mission of their department. I think, in general, though, I see where our missions tend to overlap more than how they differ just because of the nature of the work".

Communications with the non-expert public could be diverse. Besides working together through formally organized storm response structures, managers might also address public calls about tree issues before or after storms. For example, in Minneapolis, an interviewee said, *"… we do rely a lot on people letting us know, we have, I think, 700 miles of roadway, so that's impossible to police ourselves, so we rely on the public to let us know, a lot of times"*. Some interviewees described leaving these communications to designated departments, others mentioned talking one-on-one with residents, and several had social media outlets to communicate with the public. Interviewees in Philadelphia and Jacksonville described public participation as intentional and incorporated into management processes for long-term planning, such as in the development of management plans. Such communication included listening to and acknowledging that communities might have legitimate reasons for not wanting to add trees to their neighborhoods, sometimes based on past tree damage. For example, one interviewee described, *"… it's expensive to get your trees properly managed, especially as they age"*. One nonprofit manager described the lack of trust in the city as a barrier to communication and collaboration with the public, especially in ethnically diverse or lower-income neighborhoods.

Overall, conflicts around tree management and storms focused on aesthetics, priorities, perceived tree functions, unclear communication, lack of support, disagreements about tree placement and removal, and diverse uses. Each institution had several smaller goals unique to their needs or contexts, sometimes initiating disagreements. For example, one interviewee described exclusion from sidewalk planning projects early on and consequently had to deal with increased risks caused by construction-damaged roots later. Three nonprofit interviewees discussed storm-related conflicts influencing tree selection and planting; one described choosing to omit species known to split or drop limbs and advocated for proper maintenance of young trees, including structural pruning. These nonprofit staff preferred to plant the largest tree possible for a given space, even if smaller trees had a lower risk, and they believed perspectives about trees differed between institutions, leading to friction.

5. Discussion

In this study, we assessed how urban forestry professionals prepared for, responded to, and collaborated to address storms in Jacksonville, Philadelphia, and Minneapolis, including perceptions of risk, management, and storm impacts, how community vulnerability was understood, communication and conflict, working with vulnerable populations, and suggestions to improve storm preparedness. Our findings underscore the importance of sufficient resources, management challenges, variation in risk assessment strategies, and perceptions about tree species selection in managing urban trees for storm events. Our interviews also show variability in how managers understand urban forests' social and ecological vulnerability during storms. Finally, our research highlights the role of collaboration in storm-related tree risk management and associated conflicts.

5.1. Challenges to managing urban trees and storms

Given the widespread challenges facing US municipal forestry, including under-resourced departments, management that is often oriented around the latest crisis (Hauer & Peterson, 2016; Healy et al., 2023), and the timing of our research during the COVID-19 pandemic, securing interviews for this study was quite challenging. Indeed, this challenge speaks to a recurring theme from our interviews: capacity and funding difficulties. Across the three cities, insufficient resources such as time, funding, and staff were the most important challenges to storm risk management. These gaps in institutional capacity have also been noted as problems that can lead to poor survival of recently planted trees (Breger et al., 2019) Furthermore, tree maintenance budgets at municipal levels can be under-prioritized or cut in favor of other public services deemed more essential (e.g., schools, police departments, roads) (Vogt et al., 2015). Limited budgets may be temporarily ameliorated by increasing the time between tree pruning cycles; however, this may increase long-term costs and challenges like increased public requests for tree service, structural defects, and increased storm risks (Vogt et al., 2015). These resource limitations encourage immediate reactive hazard management instead of proactive management choices (Judice, Gordon, & Brodbeck, 2023). While limited staff and budgets were consistently highlighted as barriers in our study, it is also important to acknowledge that increasing budgets and staffing might not significantly enhance urban resilience to storms if other issues regarding communication, risk aversion, and ineffective collaboration within and between agencies and organizations are not improved (Ordóñez et al., 2020).

Lack of long-term planning and aging infrastructure were recognized as key challenges affecting the management of storms and urban trees. Our results emphasized the need for proactive long-term planning across all three cities. Although our interviewees' departments and programs were under-resourced, they also acknowledged the gap between current reactive approaches to storm-related risk management and the limited but crucial long-term planning needed to effectively manage storms and urban trees. These results are not unique to our study, as other research has found that municipal parks and recreation departments across the U.S. are unprepared for the impacts of climate change (Cheng et al., 2021). These departments only manage reactively unless there are serious firsthand direct impacts from climate change that can motivate them to engage in long-term adaptation planning (Cheng et al., 2021). In addition, our results highlight the recurrent issues associated with aging infrastructure, such as additional stress on trees, roads, and properties, increased financial costs for maintenance and repairs, and creates additional burdens on adjacent urban populations.

5.2. Standards of risk, preparation, and response to storm events

Risk assessments are developed and used in various ways, sometimes differing by city and institution. Although utility managers used risk assessment standards, none of the non-profit or volunteer-based groups incorporated risk assessments. This is noteworthy, given the prominent role of non-profit organizations in urban tree-planting campaigns (Eisenman et al., 2021), but not surprising considering that non-profit tree planting programs tend to be involved at the beginning of the tree life cycle, not the end when risk management issues take on more prominence (i.e., mature tree failure and removal). Previous research shows that credentials and experience influence how professionals assess tree risk, with more advanced arborists specifying that specific risk assessment criteria are necessary (Koeser, Klein, Hasing, & Northrop, 2015). For example, arborists certified by the ISA are more likely to rate the likelihood of tree failure lower than arborists without this credential (Koeser & Smiley, 2017). When conducting tree risk assessments, TRAQ-certified arborists are more likely to recommend retaining and monitoring a tree instead of tree removal than their non-TRAQ counterparts (Koeser & Smiley, 2017). The ISA's Tree Risk Assessment Best Management Practices (Smiley et al., 2017) are often used in municipalities as a method of tree risk assessment (Koeser et al., 2016). However, discussions with urban forest professionals in our study suggest that learning risk assessment skills and practices also comes from on-the-job experience and is shaped by what is accepted by each organization.

Our results underscore that storm events can influence the tree species considered, selected, and planted. Storms impact tree species selection because of concerns about hardiness, limb or whole tree failure, the potential for property damage or personal injury, and adaptation to climate change. In our interviews and others' findings, many management professionals across cities and job roles described preferring to plant the 'right tree' in the 'right place' to avoid infrastructure damage (Vogt et al., 2015). This might mean planting smaller trees in smaller planting areas or larger trees in spaces where they will not interfere with sidewalks or utility infrastructure (Magarik, Roman, & Henning, 2020). However, it is also important to note that tree species selection and diversity are significant considerations for climate change adaptation and resilience in these cities. These findings emphasize growing concerns about the lack of urban tree diversity and the potential consequences of increased vulnerability to pests and diseases, canopy loss, and the compounded impacts of climate change (Hilbert, Koeser, & Northrop, 2020). Therefore, our study echoes the need for serious consideration of tree species selection, including aesthetics, climate change, and the legacy impacts of the lack of tree diversity (including evenness and richness) in these cities.

5.3. Perceptions of vulnerability and working with the public

Our findings also highlight the factors urban forestry professionals consider when determining an area's vulnerability to climate and storm events. Social and ecological vulnerability is an important consideration for managing climate risks within urban areas because it can have important implications for reducing or amplifying disaster risks in vulnerable communities (Gu et al., 2018). Although various socio-ecological factors impact an area's vulnerability to storms, social vulnerability to climate change highlights concerns around climate justice, inequalities, health, and safety (Otto et al., 2017). Some respondents described contradictory information about high- and low-income areas being vulnerable to storms. For respondents, local contexts mattered in how they talked about risk and vulnerability, and they described specific neighborhoods with diverse maintenance histories and needs. The socio-demographic variables, neighborhood characteristics, and historical legacies highlighted by our interviewees reflect similar research that studied urban flood vulnerability in six U.S. cities and found that social metrics (e.g., gender, age, education, income, population density), ecological factors (e.g., relative levels of green space per block or neighborhood, land use) and technological indicators (e.g., building structure, materials, emergency services, the proportion of low-cost buildings) can impact an urban areas' flood vulnerability (Chang et al., 2021). However, our results also highlight that there is a lot of uncertainty among professionals about what makes some areas and populations more vulnerable to storm events, including ambiguity about the best approaches to help alleviate these conditions, given their limited capacities. This response is not unique to these cities as many urban climate resilience plans do not acknowledge or prioritize historical legacies of inequity and may unintentionally increase the vulnerability of marginalized communities (Shokry, Connolly, & Anguelovski, 2020). Therefore, more research is needed to better understand how urban forestry professionals interact with, and serve vulnerable communities.

Our participants described challenges with a lack of resources, such as staff and funding, which is consistent with other research on local capacity challenges in urban forestry (Hauer & Peterson, 2016; Breger et al., 2019). Some cities have limited capacity to conduct tree risk assessments, communicate with residents, and care for trees in a manner that reduces the risk of tree failure (Judice et al., 2023). Communities of Color and low-income communities encounter barriers to participation and engagement, sometimes including a reluctance to add trees to neighborhoods (Riedman et al., 2022). Concerns about maintenance costs and damage caused by mature trees have been highlighted as a limitation for communities to accept trees (Leets et al., 2022; Riedman et al., 2022). Just as professionals are challenged by the lack of resources allocated to tree management and maintenance, residents face similar concerns about the costs and risks of adding trees to their communities (Riedman et al., 2022; Carmichael & McDonough, 2019). In both Jacksonville and Philadelphia, management professionals described situations in which they believed communities needed to be engaged in urban forest management. Community trust in tree management institutions can be challenging to develop, especially in communities that have inherited poorly maintained trees due to municipal disinvestment (Riedman et al., 2022). To address some of these problems, Eisenman, Roman, Östberg, Campbell, and Svendsen (2024) recommend that equal resources be allocated to the pre-planting, installation, and post-planting phases of urban tree planting initiatives (Eisenman et al., In press).

New municipal strategies and investments can potentially overcome these challenges. For example, the recently released urban forest plan in Philadelphia proposes various strategies to improve tree management, including storm-related issues: assisting residents in dealing with tree burdens, investing in proactive inspection cycles, minimizing tree-infrastructure conflicts, rebuilding trust with residents, and improving coordination across agencies and stakeholder groups (Parks (PPR)., 2023). Major storm events that cause severe tree canopy loss can also sometimes catalyze tree planting, management plans, and new collaborations across institutions, as happened in Cedar Rapids, Iowa, following a derecho (Inc, 2022). Future research could examine how urban forest plans address risk management, storms, and coordination.

Storms catalyze collaboration opportunities by uncovering needs, shortcomings, and overlaps in organizations' goals. Despite a willingness to collaborate on larger goals like safety, some interviewees reported struggling to share information and coordinate. Although organizations collaborate in emergency response activities, collaborating on proactive actions like planting and pruning appears to be more challenging. Hauer and Peterson (2016) reported that only 26 % of communities throughout the U.S. have advanced coordination about trees and emergency planning (proactive management), whereas 48 % coordinate during a storm event (reactive management). Our results suggest that building personal relationships and sustained communication across organizations and agencies may help promote greater coordination.

Overall, our interviewees emphasized the importance of collaboration, especially trust. Trust is critical for the development of collaborative work with communities. Communities may express mistrust toward agencies that do not develop continual and sustained engagement efforts (Riedman et al., 2022). Partnerships and collaborations may improve tree hazard mitigation (Judice et al., 2023). Our results are consistent with other research highlighting that resident participation can shape storm response and includes multidirectional communication between organizations and the public (Judice et al., 2023).

6. Opportunities for future research

Our research presented an overview of how various professionals in utility, emergency, parks and recreation, and non-profit management manage urban trees and storms in Philadelphia, Minneapolis, and Jacksonville. Our findings highlight key insights about collaboration, risk perceptions, and community engagement, while also revealing the need for more in-depth future research. First, there is a need to understand how various urban areas respond to different climate and severe weather events, including how urban tree management varies based on hurricanes, snowstorms, tropical storms, or other events. Second, our study only focuses on Philadelphia, Minneapolis, and Jacksonville. Future research could expand on the vulnerability of other cities within the U.S. and globally to increased threats of weather events, especially in coastal areas. Third, future research may benefit from differentiating between species richness, distribution, and composition to allow researchers to understand how cities differentiate these attributes in their storm risk management.

This last point warrants further elaboration because interactions between the public and tree professionals are at the center of everyday arboricultural and urban forestry practice. Urban forestry professionals often have differing perceptions from the non-expert public about storms and tree-related risks (Kirkpatrick et al., 2013). Although our interviewees emphasized the importance of communicating and working with the non-expert public, community members may perceive higher risks than professionals, especially if they have experienced ecosystem disservices related to storms and trees (Conway & Yip, 2016). For example, fear of falling limbs and inflation of risk perceptions can lead to unnecessary removal or mitigation decisions (Klein et al., 2019), thereby adding more strain to urban forestry staff and limited resources. Our study suggests a need to study public knowledge and education strategies about balancing tree risks and benefits, especially in vulnerable communities. Previous researchers suggested that increasing engagement between trained arborists and community residents about tree risk and appropriate pruning can reduce risk (Drew-Smythe et al., 2023) because the public needs to understand the relationship between tree species and storm impacts (Kirkpatrick et al., 2013). In some cases, urban residents who were more educated about trees acknowledged more tree benefits and were less likely to have conflicts about tree placement (Fernandes, da Silva, Teixeira, & Costa, 2019). However, our results highlight that there are also other critical issues to effectively addressing storms and urban tree management, such as aging infrastructure, limited resources, and the overall need for more long-term planning and attention to building trust between residents and municipal arborists and foresters.

7. Conclusion

Urban tree management can present benefits and/or risks depending on many factors such as species, location, history, quality of care and previous encounters with storm events. In a changing climate where cities face uncertain conditions and increasing storms, it is critical that associated risks are accounted for in urban forest management plans and planting campaigns so that the ecosystem services of urban trees outweigh their disservices. This is especially relevant given the increase of large-scale urban tree planting initiatives. Although there is growing research about the impacts of climate change and storms in urban areas, there is limited research examining how cities manage urban trees, prepare and respond to storms, and the complex ways in which managers perceive community vulnerability, collaboration within and between institutions, and working with the public. Our study adds important insights to the literature by conducting a comparative assessment of urban forestry professionals in three U.S. cities to investigate how different institutions and professionals manage storms and urban trees. We found that urban forestry professionals, municipalities, and organizations that manage urban trees consider the socio-ecological dimensions of risk and make decisions to protect people, infrastructure, and urban environments. Although public safety is a priority for urban forestry professionals in reducing risks for tree crews and the public, limited resources such as budget, equipment, and staff make storm preparedness and response especially challenging for tree management professionals. Our findings indicate that multiscalar collaboration is critical to storm and tree management, and collaboration can be improved.

CRediT authorship contribution statement

Stephanie Cadaval: Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Mysha Clarke:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. **Lara A. Roman:** Writing – review & editing, Resources, Methodology, Funding acquisition, Conceptualization. **Tenley M. Conway:** Writing – review & editing, Resources, Methodology, Funding acquisition, Conceptualization. **Andrew K. Koeser:** Writing – review & editing, Resources, Methodology, Funding acquisition, Conceptualization. **Theodore S. Eisenman:** Writing – review & editing, Resources, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

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

Data availability

The data that has been used is confidential.

Acknowledgments

The authors wish to thank all of the participants in this study for generously sharing their time and expertise. This research was made possible by funding from the University of Florida and the Tree Research and Education Endowment Fund (TREE Fund) Bob Skiera Memorial Fund Building Bridges Initiative Grant Program Grant #: 20-BS-01. We thank Eric North for his efforts to connect us with urban forest professionals in Minneapolis and Ryan Klein and Larry Figart for connecting us with urban forest professionals in Jacksonville. We also thank Richard Harper for piloting the interview. The findings and conclusions of this publication are those of the authors and should not be construed to

represent any official USDA or US Government determination or policy.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2024.105102.

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