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Recommendations for improving risk awareness, managing impacts, and delivering effective action in managing tree pests and pathogens in urban environments

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ABSTRACT

Urban trees are increasingly threatened by insect pests and pathogens, notably, but not exclusively, by accidental exotic introductions. The future health of these trees and preserving their benefits requires a full understanding of this threat and the options for its effective mitigation and management. Under the EU TREEPACT project, three interlinked studies sought to increase identification and understanding of the issues related to urban tree pests and pathogens. These comprised a systematic review of the topical global empirical evidence of impacts and their mitigation; a survey of key stakeholder groups associated with urban trees; and a case study assessment of regulations, policies, and guidance for urban trees at the city level. This short communication draws on insights from these studies and provides recommendations for future urban tree health management that consider specific urban challenges, stakeholder dynamics, and responsibilities. Together, these inform the development of activities that prevent or reduce the spread of tree pests and pathogens in urban areas, focusing on the post-border stage of the pest and pathogen invasion pathway.

1. Introduction

Trees are a core component of urban green infrastructure globally (Konijnendijk, 2022) and healthy urban tree populations offer many benefits to society (O'Brien et al., 2022); they mitigate climate change through local temperature regulation (Wang et al., 2023), add biodiversity (Threlfall et al., 2017), and are valued landscape features (Price, 2003). In towns and cities around the globe, however, trees are increasingly threatened by pests and pathogens, impacting their contribution to human well-being and the urban environment (Raum et al., 2023). The extent and nature of the rising impacts of tree pests and pathogens are often not clearly known or fully understood scientifically or in urban forest management (Raum et al., 2023), although they have been identified as primary causes of tree mortality and morbidity (Petrova et al., 2025). International trade (Liebhold et al., 2012), climatic changes (Ramsfield et al., 2016), a lack of urban tree diversity (Kendal et al., 2014), and poor growing conditions (Mullaney et al., 2015) can all lead to susceptibility of urban trees to both native and exotic tree pests and pathogens. Growing international trade is likely to further spread destructive exotic pests and pathogens around the globe (Pyšek et al. 2020). Climate change induced drought and storms/hazardous conditions can substantially weaken urban trees, whilst increasing temperatures from climate change and Urban Heat Island (UHI) effects can lead to increased pest abundance (Dale and Frank, 2017).

Exotic tree pests and pathogens are often introduced accidentally via wood products, live plants, and human movement/travel (Petrova et al., 2025). Many cities, especially larger ones, are hubs of international trade and transport, and frequently serve as the first entry point; imported plant nursery stock is also concentrated in and near urban areas (Branco et al., 2019). If exotic pests and pathogens are not rapidly detected, they can establish and spread, making eradication or containment attempts more difficult and costly (Lovett et al., 2016). In urban areas, detection and management are harder due to multiple, unclear responsibilities and difficulty accessing affected trees (Webb et al., 2023), with profound implications for the long-term future of

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urban trees. In the United States, for instance, urban trees have been declining by approximately four million per year due largely to invasive exotic pests and pathogens and rapid urbanisation (Nowak and Greenfield, 2018). In the places most affected, this can have severe cost, human health, or safety implications (Raum et al., 2023). Alongside calls to enhance the biosecurity of international trade (e.g., Pyšek et al. 2020), there is a growing recognition of the need for policymakers and urban green space managers to place greater emphasis on urban tree health and biosecurity measures (e.g., Branco et al., 2019).

The urban 'biosecurity context' is complex due to the involvement of multiple stakeholders with different interests and responsibilities for tree care (Paletto et al., 2025). A recent EU-wide study by Paletto et al. (2025) classified a wide range of stakeholder groups with a specific interest in urban tree biosecurity across European countries. These are positioned at different levels in the practical aspects of urban tree management. The activities closest to hands-on management focus on daily tree care tasks. Other groups are responsible for the physical movement of trees within the supply chains (traders, consumers, and those transporting trees). At the opposite end are stakeholders involved in strategic decision-making, who shape long-term policy and management (Paletto et al., 2025). Residents, recreationists, and nature lovers are also part of the urban tree stakeholder map. All are critical to preventing, detecting, and managing tree pests and pathogens, and must be engaged to varying degrees at different stages along the invasion pathway (Marzano et al., 2017). A prerequisite to successful involvement is a greater understanding of this growing threat, as well as possible actions that can be taken to address it (Raum et al., 2024). Moreover, owing to the distinct socio-economic and environmental conditions, urban tree pest and pathogen management requires a fundamentally different approach from that used in rural forests.

This short communication seeks to inform the development of future activities that prevent or reduce the spread of tree pests and pathogens in urban areas. First, it offers a brief overview of the impacts of urban tree pests and pathogens and the risk awareness and actions of key stakeholders. It then provides suggestions for managing pests and pathogens in urban areas, focusing on the important post-border stage of the pest and pathogen invasion pathway, followed by specific recommendations.

2. The impacts of urban tree pests and pathogens

A recent global review of the impacts of tree pests and pathogens in urban environments, under the EU TREEPACT project, found a wide range of socio-economic and ecological impacts; studies on this issue have risen since 2011 (Raum et al., 2023) (Table 1). The impacts of native as well as exotic tree pests and pathogens on urban areas can be severe, especially in terms of tree damage, tree mortality, landscape aesthetics, human health and safety, and management costs. Avoiding or reducing these requires approaches specifically suitable for urban contexts. There remain, however, evidence gaps, particularly on how tree pests and pathogens influence the climate regulating capacity of urban trees, such as local temperature regulation, flood alleviation, or soil retention. Further knowledge gaps exist for specific hazards and nuisances, liabilities, and their impacts on human safety and property (e.g., branch-drop/tree-fall) (Raum et al., 2023). Thus, current evidence of impacts does not provide a comprehensive picture, which may limit effective decision-making and quick responses.

One serious impact of tree pests and pathogens in urban areas is tree dieback or branch failure, which poses safety risks from falling limbs or even entire trees (e.g., *Massaria* disease of plane trees). Large-scale tree mortality reduces overall canopy cover, especially when dominant species are affected by virulent pests or pathogens, such as Emerald ash borer (*Agrilus planipennis*) or *H. fraxineus*/ash dieback (Raum et al., 2023). This may increase inequality in urban tree distribution and lead to reduced environmental quality with potential indirect impacts on human health (e.g., due to less shading) (Jones and McDermott, 2015; Donovan et al., 2013). Also concerning are generalist pests and pathogens that threaten multiple tree species (e.g., Asian long-horned beetle (*A. glabripennis*)) (Pedlar et al., 2020). Certain pests, such as the oak and pine processionary moths (*Thaumetopoea processionea* and *T. pityocampa*), also pose direct risks to human and animal health due to the urticating hairs on the caterpillars, which cause skin and respiratory irritation (De Boer and Harvey, 2020). Similarly, the hyper-allergenic spores of sooty bark disease (*Cryptostroma corticale)* on sycamore trees can cause severe asthma and hypersensitivity pneumonitis (Braun et al., 2021). Pest management costs can also be substantial. In the USA, the emerald ash borer (*Agrilus planipennis*), for instance, has already killed millions of ash trees (Herms and McCullough, 2014), creating a $280.5 (±79.9) million increase in annual municipal forestry budgets due to this beetle (Hauer and Peterson, 2017). Avoiding the establishment or spread of such species is crucial, and traditional approaches from (rural) forestry must be adapted to urban contexts.

Table 1
Summary of the impacts of tree pests and pathogens in urban areas (n = 100).

Ecological/Environmental impacts (95 studies)	Social/Cultural impacts (35 studies)	Economic impacts (24 studies)
• Tree damages (87) • Tree mortality (49) • Reduced tree growth (8) • Changes in tree function (6) • Weakened/stressed tree (5) • Changes in soil composition (4) • Changes in ecosystem services (3) • Indirect tree damage (due to predators of beetle larvae) (2) • Loss of tree canopy cover (1) • Changes in biodiversity (1)	• Reduced aesthetic value (15) • Human health impact (11) • Hazards affecting human safety (8) • Loss of cultural / heritage value (3) • Nuisance due to larvae/litter (3) • Impact on tourism (2) • Changes in sound/ noise level (1) • Changes in crime rates (1) • Reduced thermal comfort (1) • Pest management action affects (1) • Alteration of agroecosystem (1)	• Pest management costs (15) • Economic losses (4) • Structural damage (2) • Loss in ornamental value (2) • Loss of property value (2) • Human health-related costs (1) • Changes in fibre availability (1)

Source: Raum et al. (2023) Numbers in brackets represent the number of studies reporting impact

3. Stakeholder perceptions and actions on urban tree pests and pathogens

A recent survey of key stakeholders across Germany (e.g., arborists, horticulturalists, urban planners, landowners, hobby gardeners, and estate managers) (also undertaken as part of the EU TREEPACT project) assessed knowledge of tree pests and pathogens and responses to it (Raum et al., 2024). Of the 186 respondents, all knew of pests and pathogens, though the extent to which varied (Table 2). 76 % viewed pests and pathogens as a serious problem, yet only 51 % reported high knowledge about them and their management. Notably, some tree care professionals and arborists were unconcerned, and over half of those who worked professionally with urban trees, including city green space staff and landscape planners, only had moderate knowledge. Knowledge gaps existed for reportable quarantine pests and pathogens, such as canker stain of plane (*Ceratocystis platani*), emerald ash borer (*A. planipennis*), and *Xylella fastidiosa*, as well as for specific management response options. Only 60 % perceived people as likely vectors for the spread. While most acknowledged the severity of the issue, future urban tree health initiatives must be tailored to different stakeholder groups. Tree and green professionals (e.g., arborists, horticulturists, urban green space managers) need detailed information and training as a priority. In contrast, less engaged groups, such as real estate managers, may first

Table 2
Summary of key stakeholder survey results (n = 186).

General knowledge and concern about urban tree pests/pathogens	
I've never heard of tree pests/pathogens before	0 %
I've heard of it, but don't know much about it	3 %
I've heard of it and know something	46 %
I know a lot	51 %
Viewed pests/pathogens as a serious problem	76 %
Knowledge of destructive quarantine pests/pathogens	
I've heard of/seen Asian longhorn beetle *(Anoplophora glabripennis)**	71 %
I've heard of/seen canker stain of plane *(Ceratocystis platani)**	53 %
I've heard of/seen Emerald ash borer *(Agrilus planipennis)**	47 %
I've heard of/seen Xylella bacterial disease *(Xylella fastidiosa)* *	46 %
I've heard of/seen Red-necked longhorn beetle *(Aromia bungii)**	44 %
The most popular source of information to gain knowledge of tree pests/pathogens	
Work/colleagues	87 %
Newspapers/journals	75 %

Source: Raum et al. (2024) * Quarantine pests/pathogens requiring reporting

need awareness-raising activities (Raum et al., 2024).

On noticing infestation or infection, 88 % of the survey respondents would seek more information and consult multiple sources, such as colleagues (87 %) and journals/newspapers (75 %) (Table 2). Most (75 %) were likely to take some action, such as contacting the property owner (70 %) or the relevant local government agency (55 %), and many (52 %) would seek professional assistance. Most believed that government agencies (90 %) or tree owners/managers (89 %) should be responsible for and take action against tree pests and pathogens. However, 70 % also agreed that their own behaviour could contribute to restricting the spread, although fewer (40 %) reported applying sanitary measures, such as boot or tool cleaning. Most (73 %) said they would know who to contact when discovering a suspected quarantine pest or pathogen; however, the range of public agencies cited was high, suggesting some reporting uncertainty. Most (84 %) were willing to monitor trees for pests and pathogens and report infestations, including private landowners, recreationists, and hobby gardeners (Raum et al., 2024). As many urban trees are on private land (Klobucar et al., 2020), where awareness, detection, and knowledge are often limited, increasing tree/landowner understanding and management capacity is critical.

4. National and local policy integration on tree pests and pathogens

In a case study of the city of Munich, we explored how local urban tree policies consider tree pests and pathogens (unpublished). Keyword analysis of policy documents and city-level tree programmes found no mention of pests and pathogens, revealing little local awareness or cohesive management. Under EU Regulation 2019/2072, any suspected notifiable quarantine pest and pathogens must be reported to the relevant national (or regional) authority, with the European and Mediterranean Plant Protection Organisation (EPPO) providing the pest and pathogen lists. These then coordinate or undertake response measures, including eradication on private land if necessary (JKI, 2021). None of this legal framework or reporting guidance appeared in Munich's local tree-related documents. This disconnect between national and local biosecurity highlights potential gaps in policy integration, institutional collaboration, knowledge, and communication. However, addressing the information gap at the city level is increasingly important. Despite clear EU procedures, local urban implementation is fragmented as responsibilities vary depending on the pest or pathogen, tree location, or ownership, creating confusion and barriers to non-experts.

5. The biosecurity regulatory context in urban settings and pest and pathogen management

Urban plant biosecurity is a priority as the risks from exotic tree pests and pathogens rise. Biosecurity risk measures can be divided into three stages: 1) Pre-border activities aimed at preventing pest or pathogen introduction into a country; 2) At border inspections of incoming commodities (including containers or packaging) targeting points-of-entry (interception); and 3) post-border activities aimed at first detecting and eradicating early-stage invasions, followed by long-term control measures of those that got established (Vashist et al., 2025) (Fig. 1). Preventing the introduction of exotic pests and pathogens represents the most cost-effective strategy (Carnegie and Nahrung, 2019). Under international plant protection regulation, these measures focus on listed exotic priority or quarantine pests and pathogens,[1] i.e., those whose potential economic, environmental, or social impact is considered most severe (EPPO, 2025). In the EU, twenty pests and pathogens are currently listed (EPPO, 2025). To avoid or reduce impact, stakeholders from diverse fields must be engaged to varying degrees at each stage. As biosecurity measures at or before national borders cannot entirely prevent introductions, robust post-border strategies are essential (Carnegie and Nahrung, 2019); our focus here will be on these. Surveillance, eradication, and control of exotic tree pests and pathogens in urban areas is challenging. Biosecurity efforts to date tend to have targeted rural forests within established institutional frameworks, which are not easily applied to urban contexts where responsibilities are often fragmented and ambiguous. Urban tree management is also more visible and subject to scrutiny from diverse stakeholders with varying views and knowledge levels. Actions like tree removal or heavy pruning can provoke public resistance (Collins et al., 2019), requiring clear communication with residents and private tree owners.

6. Post-border pest and pathogen management

Post-border biosecurity detection for eradication aims to discover invasive exotic species that evade interception at entry points and may have dispersed locally or been transported further (Poland and Rassati, 2019). The impact, at this point, will be very localised. In addition to targeted surveys by experts at high-risk sites, such as ports, airports, and major transport corridors, and using sentinel trees (Carnegie et al., 2022), surveillance of strategic urban places may increase early detection of harmful exotic species (e.g., nurseries, garden centres, botanic gardens, parks). Here, a widening of stakeholder engagement, especially to the tree trade/nursery sector, a 'key vector' for tree pests and pathogens, is essential (Marzano et al., 2015). Integrating biosecurity surveillance into routine urban tree health inspections could improve early detection, accelerate responses, and reduce local impact and costs (Epanchin-Niell and Liebhold, 2015). Although early detection activities will incur expenses, the costs of damage caused by invasive exotic species once established often outweigh these (Cuthbert et al., 2022). Suitable early biosecurity surveillance methods can be divided into *on-the-ground activities*, such as installing generic traps across a region, simple trapping techniques, and bio surveillance to monitor beetle communities, using predatory wasps, or *aerial surveys* via remote sensing or hyperspectral imagery to detect tree damage from above, or a combination of these (Poland and Rassati, 2019). A comprehensive discussion of these methods can be found, for instance, in Poland and Rassati (2019) and Carnegie et al. (2023).

Upon detection, public authorities will initiate *eradication measures*, including on private land, in line with biosecurity protocols (JKI, 2021). These can be grouped into *chemical* and *physical measures* (Vashist et al., 2025). Depending on the available resources, site conditions, proximity to the public, and type of pest or pathogen, these are likely to include using pesticides (e.g., foliar spray or trunk injections), removing the pest or the infested tree (and/or branches, leaves), or, in some instances, surrounding host trees. Infested plant material must be safely disposed

[1] The EU/EPPO define priority pests as quarantine pests that are not known to be present in the Union territory, present either in a limited part, or have scarce, isolated and infrequent presence in its territory (JKI, 2021).

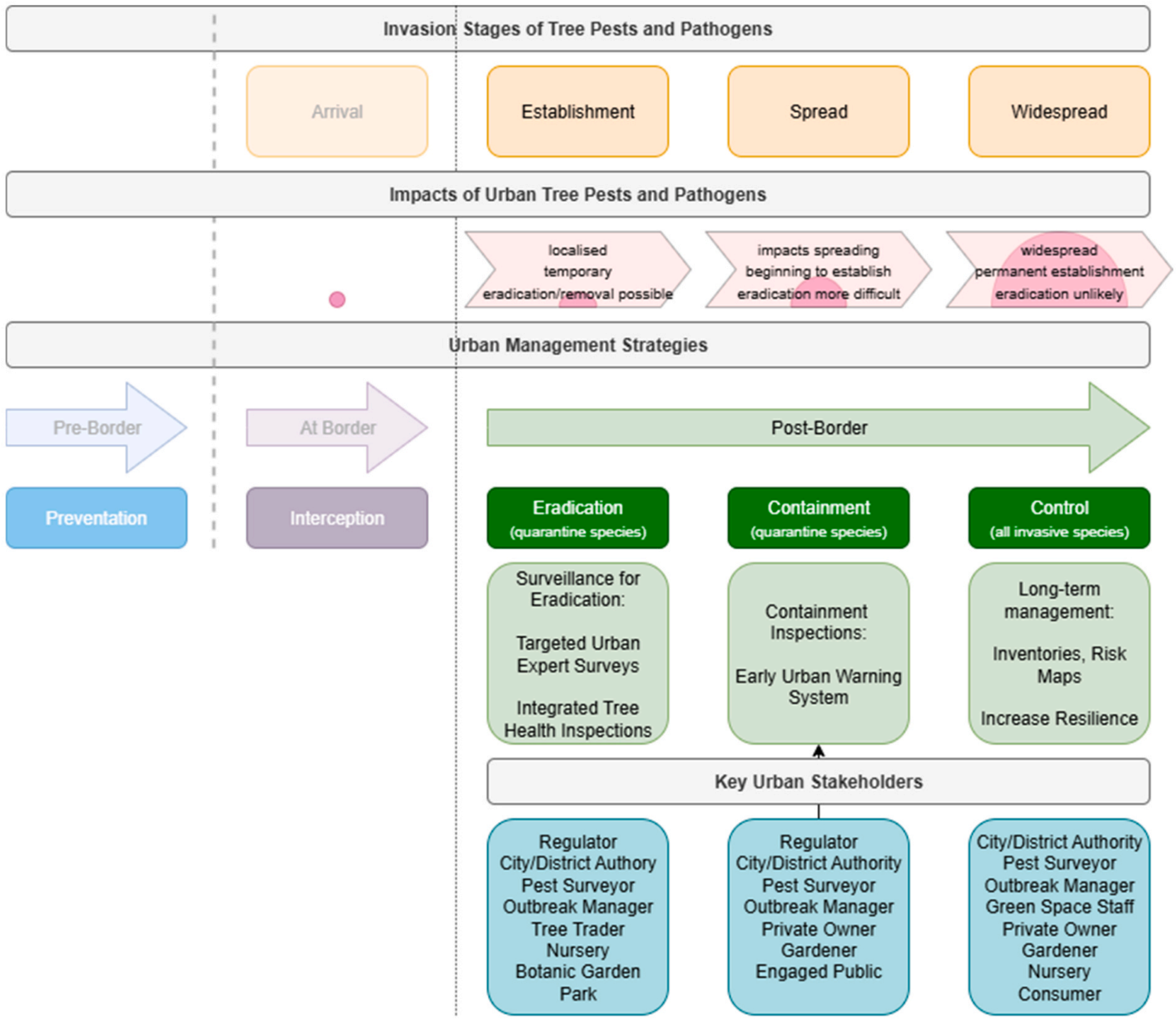

Fig. 1. Summary of processes of urban tree pest/pathogen management (adapted from Green et al., 2023; Carnegie et al., 2022; Vashist et al., 2025).

of or destroyed according to the relevant biosecurity protocol (Carnegie and Nahrung, 2019; Liebhold and Kean, 2019). Rapid responses when affected areas are still small, combined with quarantine restrictions, can lead to high eradication success (Branco et al., 2023). Public support for such pest or pathogen eradication activities, especially those involving pesticides or tree removal, is vital in urban areas (Liebhold et al., 2016). Thus, outbreak managers require training in public engagement and communication when undertaking these (Raum et al., 2024). Effective integrated programmes will also involve pest and pathogen reporting, phytosanitary and control measure coordination, and ideally, shared data platforms (Orlova-Bienkowskaja, 2013). This requires clearly defined and communicated responsibilities and a high level of coordination by regulatory authorities. In Australia, as in other countries, many plant pests and pathogens were already widely spread and well established when they were detected, rendering eradication no longer a cost-effective option (Anderson et al., 2017).

Containment surveillance surrounds known outbreaks to monitor and detect further spread. When a quarantine species is known to occur in a limited area, visual inspections by experts or trained volunteer citizens, combined with sampling of potentially infested plant parts on symptomatic or asymptomatic trees, can be used to detect the presence of hidden pests or pathogens (i.e., larvae) and thus identify infested trees. Recently developed portable genetic field tools can be used for swift on-site identification of the specimens. If available, sentinel trees and single-lure traps can capture active beetles. Remote sensing, sniffer dogs, laser vibrometry, and acoustic sensors can further support visual inspection (Poland and Rassati, 2019). The general public, through participatory approaches, such as citizen science programmes, can also monitor and report trees showing signs of infestation (Gupta et al., 2022; Poland and Rassati, 2019). In fact, the probability of eradication success can be greater when private citizens report pest presence, compared to pre-emptively searching high-risk sites (e.g., nurseries, sawmills, industrial sites). Public awareness programmes can offer substantially broader surveillance capabilities than those focused solely on searching hosts and habitats undertaken by government employees (Tobin et al., 2014). Engaging tree owners and gardeners through participatory programmes, especially, could improve detection capacity (Raum et al., 2024). Although outcomes may vary between countries, we found a strong willingness to participate within some urban groups (Raum et al., 2024). In cities, however, landowners or residents may also hesitate to report pests and pathogens as they can fear biosecurity measures such as pre-emptive felling of host tree species, which could incur costs and be visually impactful (Porth et al., 2015). Thus, in urban areas, 'rapid response management' can conflict with the impacts of eradication measures (Porth et al., 2015). Successfully engaging non-professionals, therefore, requires awareness raising, support, and training about tree pests and pathogens and their impacts, as well as relevant biosecurity regulations and procedures (Raum et al., 2024). Strengthened city- and district-level governance and coordinated action across public and private sectors are critical at this stage.

Long-Term Urban Pest Management: Long-term control and impact reduction are essential if widespread eradication is no longer possible (Carnegie and Nahrung, 2019). Urban stakeholder engagement broadens at this stage and shifts towards mitigation and adaptation (Paletto et al., 2025). Integrated pest management, tailored to local conditions and combining multiple strategies, has been widely recommended (e.g., Kovač et al., 2021; Chouvenc and Foley, 2018). These must include trees on private land. Up-to-date urban tree inventories, combined with tree density and risk maps, and regular tree health inspections are critical to providing comprehensive knowledge of an urban treescape (Rossi et al., 2016; Christen et al., 2024). Tree inventories documenting species, overall condition, and size are essential for assessing the scope and extent of potential risks. They can also help identify particularly valuable trees- such as those notable for their size, species, location, or cultural and historical significance. Conversely, trees that are structurally compromised, have surpassed the capacity of their site, or exhibit other significant issues are generally considered poor candidates for treatment (Sadof et al., 2023). In the case of protecting ash trees from EAB, for instance, mature, healthy trees will likely be prioritized for treatment because they are more costly to remove and will take years longer to replace than small trees (Sadof et al., 2023). While international plant biosecurity regulation focuses on invasive exotics, greater integration of any pests or pathogens that are high risk in terms of urban tree mortality, disbenefits to human health and safety, and costs, would benefit long-term urban pest management programmes.

Improving overall tree health and resilience is equally important in long-term urban tree management. It involves *increasing species and genetic diversity* (Raupp et al., 2006), *improving growing conditions* and *tree management* (Bukowski et al., 2019), and more *careful site-species selection* (Vogt et al., 2017). Global urban tree inventories reveal that while the most common tree species typically account for 20 % of a city's trees, this figure can exceed 40 % in some areas, increasing vulnerability to pests and pathogens (Lohr et al., 2016). Enhancing species, genus, and genetic diversity helps mitigate these risks (Zainudin et al., 2012), particularly among street trees, where diversity should be actively monitored and managed (Sanders, 1981). Urban tree resilience also depends on improving growing conditions (Bukowski, 2019), including through shared rooting zones, permeable pavements, suspended sidewalks, improved soil quality and volume, and adequate irrigation (Greene and Millward, 2016; Somerville et al., 2018). To support healthy root development, tree planting should follow best practices for planting depth and root preparation (Sherman et al., 2016). Poor tree management practices, such as improper planting, inadequate pruning, and insufficient irrigation can significantly compromise the health and longevity of urban trees and should be enhanced (Sjöman and Nielsen, 2010). Poorly executed pruning cuts can expose branches to pests and pathogens. Sanitary measures, including the cleaning of tools and removal of debris, are essential to prevent the spread of pests and diseases between trees (Kopačka et al., 2021). Careful site-specific species selection is essential to ensuring trees are planted where environmental conditions, such as soil, moisture, climate, light, and space, match the species' requirements. Poor species-site matching can lead to poor growth, increased maintenance, and vulnerability to pests and pathogens (Hitchmough, 2017). Urban forestry practices increasingly emphasize climate-resilient, stress-tolerant species and diversity to enhance long-term adaptability and reduce risks (Roloff et al., 2009). To improve urban forest resilience, strategies must engage tree managers and the wider community, including those overseeing private gardens (Bukowski, 2019).

7. Conclusion and recommendations for future urban pest and pathogen management and research

Managing invasive tree pests and pathogens in urban areas presents distinct challenges. Future strategies must improve alignment between local and national responses through better coordination and unified management priorities. Enhanced integration across governance levels is essential for effective urban pest and pathogen management. So is better coordination and communication at city- and district-level. Four areas of recommendation emerge to support future urban tree health:

First, strengthen surveillance of tree pests and pathogens of public and private trees at the city level. Local/district authorities can support this by providing: targeted expert biosecurity surveys at strategic urban places (ongoing); tree inventories, tree density and risk maps to support strategic surveillance (5-yearly); integrated biosecurity monitoring with routine urban tree health inspections (annually); and district-level early-warning systems involving professional arborists, tree owners, and the engaged public to enhance detection (ongoing). Such surveillance efforts should also address non-quarantine (exotic and native) pests and pathogens that threaten tree health, public safety, and infrastructure.

Second, raise risk awareness and improve knowledge of tree pests and pathogens and their management across diverse urban stakeholder groups. Local/district authorities can support this by providing accessible information on tree pests and pathogens (exotic and native) and relevant plant biosecurity regulations for arborists, tree keepers, and the engaged public; tailored information and training for the distinct needs and capacities of different stakeholder groups, from greenspace professionals to an engaged public; and accessible reporting pathways to encourage rapid action.

Third, attention should be paid to stakeholder values and perspectives and the broader social perception of management decisions. Local authorities can support this by: understanding that control of tree pests and pathogens in cities is often contentious; providing accessible public information on the causes and consequences of pest and pathogen outbreaks, as well as the rationale behind interventions; providing urban tree managers with training and financial support in stakeholder engagement and creating fora for public engagement and dialogue; and providing financial support to manage impacted trees on private properties.

Finally, undertake further research on tree pests and pathogens and their management in urban contexts, including on urban impacts of tree pests and pathogens (safety, property, liability, climate regulation); urban tree governance structures and management for trees on public and private land; urban tree health status and mortality associated with pests and pathogens; stakeholder training needs for urban tree pests and pathogens.

Together, these recommendations provide a pathway to improved management of tree pests and pathogens along the post-border pest introduction pathway within urban areas and can contribute to the long-term support of urban tree health and the benefits that a healthy urban tree canopy can provide.

CRediT authorship contribution statement

Susanne Raum: Funding acquisition, Conceptualisation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **C. Matilda Collins:** Conceptualisation, Methodology, Visualization, Writing – review & editing. **Julie Urquhart:** Conceptualisation, Methodology, Writing – review & editing. **Monika Egerer:** Funding acquisition, Supervision, Conceptualisation, Writing – review & editing. **Stephan Pauleit:** Funding acquisition, Conceptualisation, Supervision, Writing – review & editing.

Declaration of Competing Interest

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

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References

Anderson, C., Low-Choy, S., Whittle, P., Tylor, S., Gambley, C., Smith, L., Gillespie, P., Löcker, H., Davis, R., Dominiak, B., 2017. Australian plant biosecurity surveillance systems. Crop Prot. 100, 8–20.

Branco, S., Douma, J.C., Brockerhoff, E.G., Gomez-Gallego, M., Marcais, B., Prospero, S., Franco, J.C., Jactel, H., Branco, M., 2023. Eradication programs against non-native pests and pathogens of woody plants in Europe: which factors influence their success or failure? NeoBiota 84, 281–317.

Branco, M., Nunes, P., Roques, A., Fernandes, M.R., Orazio, C., Jactel, H., 2019. Urban trees facilitate the establishment of non-native forest insects. NeoBiota 52, 25–46.

Braun, M., Klingelhöfer, D., Groneberg, D.A., 2021. Sooty bark disease of maples: the risk for hypersensitivity pneumonitis by fungal spores not only for woodman. J. Occup. Med Toxicol. 16, 2.

Bukowski, E., 2019. Using the commons to understand the Dutch elm disease epidemic in syracus, NY. Geogr. Rev. 109 (2), 180–198.

Carnegie, A.J., Eslick, H., Barber, P., Nagel, M., Stone, C., 2023. Airborne multispectral imagery and deep learning for biosecurity surveillance of invasive forest pests in urban landscapes. Urban For. Urban Green. 81, 127859.

Carnegie, A.J., Tovar, F., Collins, S., Lawson, S.A., Nahrung, H.F., 2022. A coordinated, risk-based, national forest biosecurity surveillance program for Australian forests. Front For. Glob. Change 4, 756885.

Carnegie, A.J., Nahrung, H.F., 2019. Post-border forest biosecurity in Australia: response to recent exotic detections, current surveillance and ongoing needs. Forests 10 (4), 336.

Collins, C.M., Cook-Monie, I., Raum, S., 2019. What do people know? Ecosystem services, public perception and sustainable management of urban park trees in London, UK. Urban For. Urban Green. 43, 126362.

Chouvenc, T., Foley, J.R., 2018. Coptotermes gestroi (Wasmann)(Blattodea [Isoptera]: rhinotermitidae), a threat to the southeastern florida urban tree canopy. Fla Entomol. 101 (1), 79–90.

Christen, S., Brockerhoff, E.G., Gossner, M.M., Augustinus, B.A., 2024. A biosecurity perspective on urban trees in public and private spaces and trees available from nurseries. Urban For. Urban Green. 101, 128529.

Cuthbert, R.N., Diagne, C., Hudgins, E.J., Turbelin, A., Ahmed, D.A., Albert, C., Bodey, T. W., Briski, E., Essl, F., Haubrock, P.J., Gozlan, R.E., Kirichenko, N., Kourantidou, M., Kramer, A.M., Courchamp, F., Courchamp, F., 2022. Biological invasion costs reveal insufficient proactive management worldwide. Sci. Total Environ. 819, 153404.

Dale, A.G., Frank, S.D., 2017. Warming and drought combine to increase pest insect fitness on urban trees. PloS One 12 (3), e0173844.

De Boer, J.G., Harvey, J.A., 2020. Range-expansion in processionary moths and biological control. Insects 11 (5), 267.

Donovan, G.H., Butry, D.T., Michael, Y.L., Prestemon, J.P., Liebhold, A.M., Gatziolis, D., Mao, M.Y., 2013. The relationship between trees and human health: evidence from the spread of the emerald ash borer. Am. J. Prev. Med. 44 (2), 139–145.

Epanchin-Niell, R.S., Liebhold, A.M., 2015. Benefits of invasion prevention: effect of time lags, spread rates, and damage persistence. Ecol. Econ. 116, 146–153.

EPPO, 2025. EPPO's activities on plant quarantine. Eur. Mediterr. Plant Prot. Organ. ⟨www.eppo.int/ACTIVITIES/quarantine_activities⟩.

Green, S., Dehnen-Schmutz, K., Drakulic, J., Eschen, R., Orazio, C., Douma, J.C., Lunden, K., Colombari, F., Jactel, H., 2023. Awareness, detection and management of new and emerging tree pests and pathogens in Europe: stakeholders' perspectives. NeoBiota 84.

Greene, C.S., Millward, A.A., 2016. The legacy of past tree planting decision for a city confronting emerald ash borer (Agrilus planipennis) investastion. Front Ecol. Evol. 4 (27), 1–12.

Gupta, N., Slawson, D.D., Moffat, A.J., 2022. Using citizen science for early detection of tree pests and diseases: perceptions of professional and public participants. Biol. Invasions 24 (1), 123–138.

Hauer, R.J., Peterson, W.D., 2017. Effects of emerald ash borer on municipal forestry budgets. Landsc. Urban Plan. 157, 98–105.

Herms, D.A., McCullough, D.G., 2014. Emerald ash borer invasion of North America: history, biology, ecology, impacts, and management. Annu. Rev. Entomol. 59, 13–30.

Hitchmough, J., 2017. Urban planting design: the art and science of contemporary planting design. Routledge.

JKI, 2021. EU regelungen - Pflanzenquarantäne. julius Kühn institut - bundesforschungsinstitut für kulturpflanzen. Quedlinburg. Regel. EU Pflanz. äne Pflanz. Jul. kuehn. De.

Jones, B.A., McDermott, S.M., 2015. Linking environmental management to health outcomes: a case study of the emerald ash borer. Appl. Econ. Lett. 22 (17), 1409–1414.

Kendal, D., Dobbs, C., Lohr, V.I., 2014. Global patterns of diversity in the urban forest: is there evidence to support the 10/20/30 rule? Urban For. Urban Green. 13 (3), 411–417.

Klobucar, B., Östberg, J., Jansson, M., Randrup, T.B., 2020. Long-term validation and governance role in contemporary urban tree monitoring: a review. Sustainability 12 (14), 5589.

Konijnendijk, C.C., 2022. Evidence-based guidelines for greener, healthier, more resilient neighbourhoods: introducing the 3–30–300 rule. J. For. Res. 34 (3), 821–830.

Kopačka, M., Nachman, G., Zemek, R., 2021. Seasonal changes and the interaction between the horse chestnut leaf miner cameraria ohridella and horse chestnut leaf blotch disease caused by guignardia aesculi. Forests 12 (7), 952.

Kovač, M., Diminić, D., Orlović, S., Zlatković, M., 2021. Botryosphaeria dothidea and neofusicoccum yunnanense causing canker and dieback of sequoiadendron giganteum in Croatia. Forests 12 (6), 695.

Liebhold, A.M., Kean, J.M., 2019. Eradication and containment of non-native forest insects: successes and failures. J. Pest Sci. 92 (1), 83–91.

Liebhold, A.M., Berec, L., Brockerhoss, E.G., Epanchin-Niell, R.S., Hastings, A., Herms, D. A., Kean, J.M., McCullough, D.G., Suckling, D.M., Tobin, P.C., Yamanaka, T., 2016. Eradication of invading insect populations: from concepts to applications. Ann. Rev. Entomol. 61, 335–352.

Liebhold, A.M., Brockerhoff, E.G., Garrett, L.J., Parke, J.L., Britton, K.O., 2012. Live plant imports: the major pathway for forest insect and pathogen invasions of the US. Front. Ecol. Environ. 10 (3), 135–143.

Lohr, V.I., Kendal, D., Dobbs, C., 2016. Urban trees worldwide have low species and genetic diversity, posing high risks of tree loss as stresses from climate change increase. Acta Hort. 1108, 263–270.

Lovett, G.M., Weiss, M., Liebhold, A.M., Holmes, T.P., Leung, B., Lambert, K.F., Orwig, D. A., Campbell, F.T., Rosenthal, J., McCullouc, D.G., Wildova, R., Ayres, M.P., Canham, C.D., Foster, D.R., LaDeau, S.L., Weldy, T., 2016. Nonnative forest insects and pathogens in the United States: impacts and policy options. Ecol. Appl. 26 (5), 1437–1455.

Marzano, M., Allen, W., Haight, R.G., Holmes, T.P., Keskitalo, E.C.H., Langer, E.R.L., Shadbolt, M., Urquhart, J., Dandy, N., 2017. The role of the social sciences and economics in understanding and informing tree biosecurity policy and planning: a global summary and synthesis. Biol. Invasions 19, 3317–3332.

Marzano, M., Dandy, N., Bayliss, H.R., Porth, E., Potter, C., 2015. Part of the solution? Stakeholder awareness, information and engagement in tree health issues. Biol. Invasions 17, 1961–1977.

Mullaney, J., Lucke, T., Trueman, S.J., 2015. A review of benefits and challenges in growing street trees in paved urban environments. Landsc. Urban Plan. 134, 157–166.

Nowak, D.J., Greenfield, E.J., 2018. Declining urban and community tree cover in the United States. Urban Urban Green. 32, 32–55.

O'Brien, L.E., Urbanek, R.E., Gregory, J.D., 2022. Ecological functions and human benefits of urban forests. Urban For. Urban Green. 75, 127707.

Orlova-Bienkowskaja, M.J., 2013. Dramatic expansion of the range of the invasive ash pest, buprestid beetle agrilus planipennis fairmaire, 1888 (Coleoptera, Buprestidae) in european russia. Entomol. Rev. 93 (9), 1121–1128.

Paletto, A., Sergiacomi, C., Marzano, M., Avdibegović, M., Belka, M., Blumenstein, K., Braganca, H., Branco, M.R., Burokiene, D., Cawero, J.J.D., Dordevic, I.D., Dobsinksa, Z., Hrafnkelsdottier, B., Kacpryyk, M., Korkmaz, Y., Kicic, M., Jürisoo, L., Ipekdal, K., Janosikova, Z., Libiete, Z., Marciulyniene, D., Matosevic, D., Menhazova, J., Orlovic, S., Morales-Rodriguez, C., Papazova-Anakieva, I., Malovrh, S.P., Poljakovic-Pajnik, L., Ramos, A.P., Trestic, T., Tuba, K., Vettraino, A. M., Zlatkovic, M., Witzell, J., 2025. Collaborative approaches to urban tree biosecurity: Stakeholder's perceptions, actions and social networks. Urban For. Urban Green. 105, 128674.

Pedlar, J.H., McKenney, D.W., Yemshanov, D., Hope, E.S., 2020. Potential economic impacts of the asian longhorned beetle (Coleoptera: Cerambycidae) in eastern Canada. J. Econ. Entomol. 113 (2), 839–850.

Petrova, A., Michael, R.N., Pratt, C., 2025. What kills mature street and park trees in cities? Systematic quantitative review of published case studies. Environ. Manag. 1–21.

Poland, T.M., Rassati, D., 2019. Improved biosecurity surveillance of non-native forest insects: a review of current methods. J. Pest Sci. 92 (1), 37–49.

Porth, E.F., Dandy, N., Marzano, M., 2015. "My garden is the one with no trees:" residential lived experiences of the 2012 asian longhorn beetle eradication programme in kent, england. Hum. Ecol. 43 (5), 669–679.

Price, C., 2003. Quantifying the aesthetic benefits of urban forestry. Urban For. Urban Green. 1 (3), 123–133.

Pyšek, P., Hulme, P.E., Simberloff, D., Bacher, S., Blackburn, T.M., Carlton, J.T., Dawson, W., Essl, F., Foxcroft, L.C., Genovesi, P., Jeschke, J.M., Kühn, I., Liebhold, A.M., Mandrak, N.E., Meyerson, L.A., Pauchard, A., Pergl, J., Roy, H.E., Seebens, H., van Kleunen, M., Vilà, M., Wingfield, M.J., Richardson, D.M., 2020. Scientists' warning on invasive alien species. Biol. Rev. Camb. Philos. Soc. 95 (6), 1511–1534.

Ramsfield, T.D., Bentz, B.J., Faccoli, M., Jactel, H., Brockerhoff, E.G., 2016. Forest health in a changing world: effects of globalization and climate change on forest insect and pathogen impacts. Forestry 89 (3), 245–252.

Rossi, J.P., Imbault, V., Lamant, T., Rousselet, J., 2016. A citywide survey of the pine processionary moth thaumetopoea pityocampa spatial distribution in Orléans (France). Urban Urban Green. 20, 71–80.

Raum, S., Collins, C.M., Urquhart, J., Potter, C., Pauleit, S., Egerer, M., 2023. Tree insect pests and pathogens: a global systematic review of their impacts in urban areas. Urban Ecosyst. 26, 587–604.

Raum, S., Hossu, C.A., Lupp, G., Pauleit, S., Egerer, M., 2024. Stakeholder exposure to and knowledge of tree pests and diseases and their management in urban areas. Urban For. Urban Green. 100, 128456.
Raupp, M.J., Cumming, A.B., Raupp, E.C., 2006. Street tree diversity in North America and its potential for tree loss to exotic borers. Arboric. Urban 32 (6), 297–304.
Roloff, A., Korn, S., Gillner, S., 2009. The climate-species-matrix to select tree species for urban habitats considering climate change. Urban For. Urban Green. 8 (4), 295–308.
Sadof, C.S., McCullough, D.G., Ginzel, M.D., 2023. Urban ash management and emerald ash borer (Coleoptera: Buprestidae): facts, myths, and an operational synthesis. J. Integr. Pest Manag. 14 (1), 14.
Sanders, R.A., 1981. Diversity in the street trees of syracuse, New York. Urban Ecol. 5 (1), 33–43.
Sherman, A.R., Kane, B., Autio, W.A., Harris, J.R., Ryan, H.D.P., 2016. Establishment period of street trees growing in the Boston, MA metropolitan area. Urban For. Urban Green. 19, 95–102.
Sjöman, H., Nielsen, A.B., 2010. Selecting trees for urban paved sites in Scandinavia—A review of information on stress tolerance and its relation to the requirements of tree planners. Urban For. Urban Green. 9 (4), 281–293.
Somerville, P.D., May, P.B., Livesley, S.J., 2018. Effects of deep tillage and municipal Green waste compost amendments on soil properties and tree growth in compacted urban soils. J. Environ. Manag. 227, 365–374.
Threlfall, C.G., Mata, L., Mackie, J.A., Hahs, A.K., Stork, N.E., Williams, N.S., Livesley, S. J., 2017. Increasing biodiversity in urban Green spaces through simple vegetation interventions. J. Appl. Ecol. 54 (6), 1874–1883.
Tobin, P.C., Kean, J.M., Suckling, D.M., McCullough, D.G., Herms, D.A., Stringer, L.D., 2014. Determinants of successful arthropod eradication programs. Biol. Invasions 16 (2), 401–414.
Vashist, M., Singh, S.K., Kumar, T.V., 2025. Enhancing resilience for sustainable cities: a review of threats to urban trees. Biodivers. Conserv. 1–28.
Vogt, J., Gillner, S., Hofmann, M., Tharang, A., Dettmann, S., Gerstenberg, T., Schmidt, C., Gebauer, H., Van de Riet, K., Berger, U., Roloff, A., 2017. Citree: a database supporting tree selection for urban areas in temperate climate. Landsc. Urban Plan. 157, 14–25.
Zainudin, S.R., Mustafa, K.A., Austin, D., Helmy, J., Lingkeu, D.A., 2012. Urban trees diversity in kuching north city and UNIMAS, kota samarahan, sarawak. Pertanika J. Trop. Agric. Sci. 35 (1), 27–32.
Wang, C., Ren, Z., Chang, X., Wang, G., Hong, X., Dong, Y., Guo, Y., Zhang, Z., Ma, Z., Wang, W., 2023. Understanding the cooling capacity and its potential drivers in urban forests at the single tree and cluster scales. Sustain. Cities Soc. 93, 104531.
Webb, C.R., Avramidis, E., Castle, M.D., Stutt, R.O., Gilligan, C.A., 2023. Modelling the spread of tree pests and pathogens in urban forests. Urban For. Urban Green. 86, 128036.