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PERSPECTIVE

# Beyond 'trees are good': Disservices, management costs, and tradeoffs in urban forestry

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**Abstract** The provision of ecosystem services is a prominent rationale for urban greening, and there is a prevailing mantra that 'trees are good'. However, understanding how urban trees contribute to sustainability must also consider disservices. In this perspective article, we discuss recent research on ecosystem disservices of urban trees, including infrastructure conflicts, health and safety impacts, aesthetic issues, and environmentally detrimental consequences, as well as management costs related to ecological disturbances and risk management. We also discuss tradeoffs regarding species selection and local conservation concerns, as well as the central role of human perception in the interpretation of ecosystem services and disservices, particularly the uncritical assertion that 'everybody loves trees'. Urban forestry decision-making that fails to account for disservices can have unintended negative consequences for communities. Further research is needed regarding life cycle assessments, stakeholder decision-making, return-on-investment, and framings of services and disservices in urban forestry.

**Keywords** Ecosystem disservices · Green infrastructure · Negative synergies · Positive synergies · Urban ecosystems · Urban sustainability

## INTRODUCTION

Municipal sustainability efforts are central to meeting global environmental challenges (Elmqvist et al. 2018). Local sustainability initiatives include urban greening, a social practice characterized by efforts to introduce, conserve, or maintain vegetation in urban areas (Eisenman et al. 2019; Table 1). For instance, cities have set ambitious tree canopy cover goals and launched initiatives to plant a million trees (Young 2011; Nguyen et al. 2017). Such programs are increasingly predicated on the mainstreaming of ecosystem services among municipal foresters and tree planting advocates (Silvera Seamens 2013; Young 2013). In contemporary urban forestry (Table 1) research, ecosystem services studies are widespread (Roy et al. 2012; Haase et al. 2014; Escobedo et al. 2019). Urban trees provide important benefits to society (Fig. 1), such as shading buildings to lower air conditioning use (Ko 2018), managing stormwater (Berland et al. 2017), and improving human health (Kardan et al. 2015). Accordingly, tree planting programs are framed as a biotechnological tool (Silvera Seamens 2013) or as a nature-based solution (Escobedo et al. 2019). Language that evokes widespread appreciation for tree benefits is used by urban forestry professionals: 'Trees are Good'® is a mantra used on an educational website from a leading international arboriculture organization (ISA 2020), and the assertion that 'everybody loves trees' dominates among tree planting advocates (Braverman 2008).

Despite many documented benefits, the proposition that trees are always and only intrinsically good in all decision-making situations can be problematic for planning and designing urban landscapes. A broader consideration of urban trees for public policy and sustainability requires a balanced understanding of services and disservices (Lyytimäki and Sipilä 2009; von Döhren and Haase 2015). Assessments of urban greening focused solely on ecosystem services do not convey the net effectiveness of vegetation for addressing critical environmental challenges (Pataki et al. 2011). An important but often unacknowledged reality is that tree care activities can have environmentally negative impacts, such as exacerbating water scarcity via irrigation in arid and semi-arid cities (Jones


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**Table 1** Definitions of terms related to ecosystem services and disservices in urban forests, as used in this manuscript. Notably, some of these terms are contested (Konijnendijk et al. 2006; Fisher et al. 2009) and may continue to evolve

| Term | Definition | Citation(s) |
|---|---|---|
| Ecosystem services | "[T]he benefits that people derive from functioning ecosystems" | Costanza et al. (2017), although definitions are debated (Fisher et al. 2009) |
| Ecosystem disservices | "[E]cosystem generated functions, processes and attributes that result in perceived or actual negative impacts on human wellbeing" | Shackleton et al. (2016), see also Lyytimäki and Sipilä (2009) and Vaz et al. (2017) |
| Management costs | Direct budgetary expenses for urban forestry stakeholders to plant, maintain, and remove trees, including costs for materials (e.g., trees, equipment) and paid labor (e.g., arborists); management costs are distinct from ecosystem disservices in that disservices are not on stakeholders' accounting ledgers | This manuscript, but see Vogt et al. (2015) |
| Negative synergy | A lose–lose situation that involves a mutual increase in ecosystem disservices, with an implied reduction in ecosystem services; also called "jointly negative" outcomes; more broadly speaking, negative synergies are situations in which the holistic impact is worse than each individual component | This manuscript, but see Jackson and Mathews (2011) and Persha et al. (2011) |
| Positive synergy | "[A] win–win situation that involves a mutual improvement of two ecosystem services", with an implied reduction in disservices; more broadly speaking, positive synergies are situations in which the holistic impact is greater, and more beneficial, than each individual component | Felipe-Lucia et al. (2015) and Jackson and Mathews (2011) |
| Tradeoff | Often refers to a "[s]ituation in which land use or management actions increase the provision of one ecosystem service and decrease the provision of another", but could also refer to a situation in which an ecosystem service increases while disservice(s) also increase (i.e. win-lose) | Felipe-Lucia et al. (2015) |
| Tree risk management | The application of policies, procedures, and practices to identify, evaluate, mitigate, monitor, and communicate risk regarding trees in urban areas, including assessments of likelihood of tree failure (i.e., tree or limbs falling) and consequences of failure (i.e., injury, property damage, utility damage) | Dunster et al. (2013) and Klein et al. (2019) |
| Urban greening | "[O]rganized or semi-organized efforts to introduce, conserve, or maintain outdoor vegetation in urban areas" | Eisenman et al. (2019) |
| Urban forest | The system of trees in cities, suburbs, towns, and other urbanized areas, including public and private lands, spanning street trees and residential yards as well as highly designed and natural parks | Miller et al. (2015) |
| Urban forestry | The management and study of trees and forest resources in urbanized areas; some definitions explicitly call out management objectives for environmental, social and economic benefits; the practice of urban forestry is closely related to urban greening, but urban forestry has distinct disciplinary traditions and professional spheres | Konijnendijk et al. (2006) |

and Fleck 2018) and producing greenhouse gas emissions (Reid et al. 2010; Petri et al. 2016).

Besides critiques centered on net environmental impacts, there are many other considerations for stakeholder decision-making in urban forestry. These stakeholders include municipal leaders, tree professionals in parks and public works departments, nonprofit organization staff, landscape architects, city planners, contractors, and residents (Lawrence et al. 2013; Nguyen et al. 2017; Breger et al. 2019). For instance, arborists working in the commercial, utility, and municipal sectors spend much of their time addressing ecosystem disservices related to the negative impacts of trees on built infrastructure and human safety (Hauer and Peterson 2016). This work includes tree risk management (Table 1) to assess the likelihood of trees or limbs falling (Fig. 2a) and limit injury, death, property


**Fig. 1** Urban trees can provide a variety of benefits to society, including beautification and shade provision that promote walkable streetscapes (**a** Philadelphia, PA, USA) and parks (**b** Malmö, Sweden). Photos courtesy of L Roman and J Östberg


**Fig. 2** Ecosystem disservices associated with urban trees include property damage from storms (**a** Winter Storm Riley, Bala Cynwyd, PA, USA) and nuisances from litter (**b** Malmö, Sweden). Photos courtesy of J Bond and J Östberg

damage, and power outages (Klein et al. 2019). Deciding whether or not to remove trees—whether risks outweigh benefits—is therefore central to the everyday labor of arborists (Hauer and Peterson 2016; Klein et al. 2019). Arborists' decisions about removal may also reflect opinions that residents or other affected stakeholders have about tree risks, with perceptions based on stakeholders' beliefs about tree services and disservices (Conway 2016; Tian et al. 2020).

Even though tree disservices, in terms of potential damage from trees, are central to the work of professional arborists (Koeser et al. 2016), and to some residents' perceptions about trees (Conway 2016), ecosystem services studies dominate urban forestry research. In a systematic review of 115 studies of urban tree services and disservices over several decades, only 16% demonstrated or discussed disservices (Roy et al. 2012). As a prime example, a survey of municipal arborists found that 73% viewed themselves as engaged in the production of ecosystem services (Young 2013)—but the participants were not even asked about disservices. While more studies on urban tree disservices have been published since the Roy et al. (2012) review (e.g., Dobbs et al. 2014; Tian et al. 2020), the dominance of ecosystem services is hardly surprising, given that commonly cited definitions of urban forestry explicitly emphasize the provision of environmental, social, and economic benefits as a goal of management (Miller et al. 2015; Table 1). Nevertheless, we suspect that many stakeholders have nuanced perspectives about trees, recognizing an array of beneficial and detrimental impacts in specific decision-making situations. The ecosystem services/disservices dichotomy is, in turn, an academic construction (Saunders and Luck 2016) that may not express the diversity of stakeholders' perceptions about urban trees. Moreover, Vaz et al. (2017) asserted that ecosystem services and disservices are fundamentally coupled concepts, and discussion of one must also recognize the other.

In this perspective article, we discuss recent studies about ecosystem disservices in urban forestry and suggest that services and disservices can be better integrated into stakeholder decision-making by evaluating tradeoffs and synergies. We ground interpretations of ecosystem services and disservices in the perceptions people hold about urban trees, including their attitudes, preferences, beliefs, and values. Because management costs are also tied to stakeholder decision-making, and have been viewed by past researchers as a type of disservice (Lyytimäki 2017; Escobedo et al. 2019), we discuss the relationship between management costs and services/disservices. We focus on the parts of the urban forest (Table 1) that are most immediately affected by human decisions (i.e., not forested natural areas in cities)—sidewalk planting spaces, residential yards, and landscaped parks. Trees in such landscapes are the direct products of human decisions and actions regarding planting, maintenance, and removal (Roman et al. 2018). Urban tree communities in cultivated landscapes are thus anthropogenically-constructed systems in which humans control population cycles and community structure, albeit with continued influences from biophysical drivers, such as climate (Roman et al. 2016; Jenerette et al. 2016; Roman et al. 2018).

As a group of coauthors devoted to the study of urban environments, we closely collaborate with, and deeply respect, tree care professionals. We are among the many who espouse the benefits that trees bring to our cities, yet we assert that the ecosystem services paradigm has limitations. Other scholars have similar concerns (Lyytimäki and Sipilä 2009; Vaz et al. 2017). Shackleton et al. (2016) argued that neglecting ecosystem disservices in scientific and policy discourse is problematic for well-informed landscape management that promotes human wellbeing, while Ernstson and Sörlin (2013) suggested that global dissemination of the ecosystem services paradigm risks producing homogenized urban landscapes that ignore local history, knowledge, and norms.

While appreciative of urban ecosystem services as a way to understand and promote tree benefits, we are concerned about its dominance. Our central argument is that urban forestry decision-making should consider the synergies and tradeoffs across services and disservices in order to reduce unintended negative consequences for communities and local sustainability issues.

## ECOSYSTEM DISSERVICES

Whereas ecosystem services are broadly defined as "the benefits that people derive from functioning ecosystems" (Costanza et al. 2017), ecosystem disservices are the "ecosystem generated functions, processes and attributes that result in perceived or actual negative impacts on human wellbeing" (Shackleton et al. 2016; Table 1). We summarize the ecosystem disservices of urban trees in terms of infrastructure conflicts; human health and safety; cultural, aesthetic, and social issues; and environmental and energy issues, following Lyytimäki (2017) and Vaz et al. (2017). Ecosystem services and disservices are tied to the size, species, and location of trees (McPherson et al. 2005; Shackleton et al. 2016; Ko 2018), which are a product of historical human decision-making in terms of what and where to plant (Roman et al. 2018). Services and disservices also operate at varying temporal and spatial scales: they may occur infrequently or be permanently present, and impacts may be concentrated around individual trees or across entire neighborhoods or cities (Shackleton et al. 2016; Lyytimäki 2017).

### Infrastructure

Although urban trees are now broadly framed as green infrastructure (Escobedo et al. 2019), they may conflict with nearby grey infrastructure (i.e., engineered structures including buildings and systems for energy, water and sewerage, communication, and transportation, Hamada 2015). Trees can damage grey infrastructure during storms, and managing tree-infrastructure conflicts is a major focus of arboriculture professionals (Vogt et al. 2015; Hauer and Peterson 2016). Property damage and utility service disruption are common challenges in urban forestry, and there is a growing body of literature on tree risk management to assess and mitigate these disservices (Klein et al. 2019). Storm-related tree problems point to an inherent tension in urban forest management: damage inflicted by ice storms, snow storms, and hurricanes occurs because of the spatial configuration of grey infrastructure and large trees. This motivates governance responses to ecosystem disservices that relate to storms as ecological disturbances. For example, arborists have managed the potential of utility line damage from large street trees by replacing them with short-stature species (Magarik et al. 2020). Contemporary arborists emphasize the need to plant appropriate species in suitable locations—the 'right tree' in the 'right place' (Vogt et al. 2015)—in part to move away from the historical trend for large shade trees along city streets lined with overhead wires (Dean 2005). Residents also respond to tree-infrastructure conflicts; a typical rationale for residential tree removal in Toronto is experienced or potential property damage (Conway and Yip 2016).

Trees' impacts on transportation and sewerage can also be important to stakeholders. Trees sometimes obstruct vehicular traffic and pedestrians on roads and sidewalks, and tree roots may block sewer pipes (Delshammar et al. 2015; Lyytimäki 2017). Complaints to tree officers in Sweden often involve infrastructure conflicts, including trees concealing traffic signs and roots lifting sidewalks (Delshammar et al. 2015). Although ecosystem disservices studies are fairly recent in urban forestry research (e.g., Lyytimäki and Sipilä 2009; Dobbs et al. 2014), tree-infrastructure conflicts have been recognized in urban tree management for more than a century (Dean 2005).

## Health and safety

While a growing body of literature highlights the health benefits of urban trees (Frumkin et al. 2017), these trees can also negatively impact health and safety. Large trees cause fatalities and injuries when trunks or limbs fall on people, vehicles, and buildings (Schmidlin 2009). While fatalities are rare overall, residents express storm-related safety concerns (Conway and Yip 2016). Street trees can also generate safety risks for drivers by blocking views and serving as physical hazards in vehicular accidents (van Treese et al. 2017). Trees can be a source of fear when they are perceived as a threat to personal safety, especially if the landscape is unmaintained or vegetation obstructs sightlines (Maruthaveeran and Konijnendijk van den Bosch 2014). Safety considerations also extend to the urban forestry workforce. Arboriculture can be dangerous: workers experience personal injury and even death due to falls by tree climbers, falling trees and branches, chainsaw and chipper use, and electrocutions (Ball et al. 2020). Additionally, urban trees may reduce air quality and exacerbate asthma by producing allergenic pollen, generating ground-level ozone through BVOC emissions, and reducing air pollution dispersion in dense city streets lined by buildings (Eisenman et al. 2019). These asthma-related health concerns dovetail with negative environmental impacts of urban trees (Pataki et al. 2011). The aforementioned health and safety challenges do not negate the many benefits of urban trees, but they do counter an oversimplification of trees as universally ‘good’ for human health.

## Cultural, aesthetic, and social issues

Cultural and aesthetic benefits are a recognized, but understudied, component of urban ecosystem services (Roy et al. 2012; Dronova 2019). Urban tree planting efforts in Western countries in the late 18th and early 19th centuries were tied to civic beautification movements (Roman et al. 2018), and today, aesthetic benefits are sometimes a central motivation for residents to plant trees (Lohr et al. 2004; Locke et al. 2015). Yet aesthetic disservices also exist (Lyytimäki 2017; Dronova 2019). In recent years, public annoyance with tree-related nuisances has become a well-documented disservice. Nuisance research has focused on aesthetic impacts and leaf, branch, and fruit litter created by trees (Kirkpatrick et al. 2013; von Döhren and Haase 2015; Fig. 2b). For instance, tree officers in Britain spend most of their time addressing complaints about nuisance-based disservices (Davies et al. 2017). While nuisance levels might be reduced through appropriate species selection and maintenance (Kirkpatrick et al. 2013), residents and pedestrians’ annoyance points to fundamental variation in human attitudes and preferences associated with urban trees (Teixeira et al. 2019). Furthermore, while increased property and rental costs associated with urban vegetation are often treated as financial manifestations of indirect aesthetic benefits (Irwin et al. 2017), such outcomes can also result in green gentrification that displaces vulnerable residents. Gentrification is increasingly recognized by researchers as a potential social downside of urban greening (Pearsall and Eller 2020). The possibility that urban tree planting may exacerbate resident displacement in disadvantaged communities contrasts with expectations for social benefits, such as enhancing social interaction (Maas et al. 2009).

## Environmental and energy issues

While the environmental and energy-saving benefits of urban trees are widely researched and promoted (Roy et al. 2012; Silvera Seamens 2013), there are also environmentally detrimental aspects of urban forestry, including air quality impairment, water use, greenhouse gas emissions, and invasive species (Pataki et al. 2011; Petri et al. 2016; Potgieter et al. 2019). The few life cycle assessments carried out for urban trees have shown that nursery production, planting, pruning, removal, and disposal generate carbon dioxide and other greenhouse gas emissions (including from vehicles and tree care equipment), meaning that planted urban trees are initially net emitters of carbon, and become carbon neutral only after approximately three decades when emissions are outweighed by sequestration (Petri et al. 2016). Leafblowers, chainsaws, and stump grinders also generate particulate matter (Reid et al. 2010). Carbon considerations are further complicated by climate; in cold cities, tree shade can increase wintertime building heating demands and associated carbon emissions (Erker and Townsend 2019).

Irrigation is another a sustainability challenge for urban trees (Jones and Fleck 2018). In arid and semi-arid cities where the surrounding biome is not naturally forest, irrigating urban vegetation can counteract water conservation efforts (Liang et al. 2017). Thus, the very maintenance activities which promote tree survival (and generate long-term ecosystem services like carbon sequestration) may in some circumstances have environmentally negative impacts. The tensions between irrigation demands and carbon benefits of planted trees in Los Angeles led Pincetl et al. (2013) to question whether tree planting programs there are more ‘fashion’ than ‘function’. By overlooking disservices related to irrigation, tree planting campaigns in dry cities may exacerbate water shortages.

Another environmentally detrimental aspect of urban forests is the prevalence of non-native invasive tree species, which can increase risks of wildfires, impact ecological functions, and alter habitat for native wildlife

(Shackleton et al. 2016; Potgieter et al. 2019). Some non-native trees once purported as tolerant of urban conditions have since invaded nearby natural forest ecosystems; examples include *Eucalyptus* spp. in Cape Town (Potgieter et al. 2019) and *Pyrus calleryana* in New York City (McMillen et al. 2019). Invasive tree species continue to generate ecosystem services, like carbon sequestration and sometimes aesthetic benefits, even as they have become undesirable due to conservation concerns (Vaz et al. 2017).

## MANAGEMENT COSTS

Many of the disservices of urban trees discussed above are tied to management costs. While other authors have treated direct management costs as a form of disservices (Lyytimäki 2017; Escobedo et al. 2019), we treat disservices as phenomena that are not on stakeholders' accounting ledgers (i.e., externalities). We define management costs as direct budgetary expenses for urban forestry stakeholders (Table 1). The paid labor (e.g., arborists) and materials (e.g., trees, equipment) that keep trees alive and healthy (or are used to remove them when deemed necessary) are management costs, whereas the negative impacts of trees (whether a living, thriving tree or a fallen, dead tree) on human health, the experience of daily life, and built infrastructure are ecosystem disservices.

Management costs occur through responses to ecological disturbances, routine inspections of mature trees (with pruning and removal as appropriate), and the planting and care of young trees. Urban forestry professionals broadly recognize that ongoing maintenance costs are essential to support urban forest health, ecological functions, and associated ecosystem services (Vogt et al. 2015), but stakeholder resources may be largely spent mitigating disservices. For instance, storm clean-up consumes substantial municipal resources (Hauer and Peterson 2016). This sort of crisis response, or reactive management, means that maintenance often occurs only as-needed in emergencies (Hauer and Peterson 2016).

Having a past legal claim for damage or injury caused by trees (and associated financial liability) is a predictor for cities in the United States to undertake proactive risk management activities, such as routine public tree inspections (Koeser et al. 2016). In other words, when a city experiences a sudden increase in costs due to fallen trunks or broken limbs, the response can be heightened attention to arboricultural best practices. The financial burden of inspecting, pruning, and removing mature trees may, in turn, limit resources available for young tree maintenance, which itself requires tremendous staff and volunteer hours to ensure tree survival (Roman et al. 2015). Municipal staff may be so preoccupied dealing with the ecosystem disservices and management costs of an aging tree population that there is insufficient labor to cultivate the ecosystem services generated by the next generation of trees, as suggested in research from both Britain and the United States (Davies et al. 2017; Breger et al. 2019). Many towns in the United States consider their urban forestry budgets to be inadequate (Hauer and Peterson 2016), leading to competing priorities to allocate resources for mature tree pruning and removal versus young tree planting and care. For residents, lack of resources also directly informs decision-making: in suburban Toronto, insufficient time and money are typical reasons for not planting trees, or not removing unhealthy trees (Conway 2016). Because management costs can impact stakeholders' capacity to sustain ecosystem services (or their response to disservices), it is important for integrated assessments to include stakeholder budgetary considerations.

As we do not consider management costs a form of ecosystem disservices, such costs are not, strictly speaking, part of the tradeoffs and synergies among services and disservices that we discuss in the next section. Yet management costs are certainly part of stakeholder decision-making, and we include costs in our evaluation matrix (Table 2). Management costs can also be evaluated through return-on-investment studies, which are used in restoration ecology and biodiversity conservation (Goldstein et al. 2008; Auerbach et al. 2014). New research into return-on-investment in urban forestry could aid decision-making, particularly to evaluate alternative responses to specific management challenges for municipal foresters. For example, a recent study estimated the divergent levels of ecosystem services that could be retained following an outbreak of *Agrilus planipennis* on *Fraxinus* spp., depending on decisions to preemptively remove, replace, or treat and retain the trees (Vannatta et al. 2012).

Notably, early ecosystem service studies about street trees incorporated both benefits and management costs. For example, the Chicago Urban Forest Climate Project in the 1990s concluded that "despite the expense of planting and caring for trees in Chicago, with time the benefits that healthy trees produce can exceed their costs" (McPherson et al. 1994, v). Studies about street tree ecosystem services reported benefit:cost ratios through the 1990s and early 2000s: costs reflected municipal expenditures (e.g., planting, pruning, removal, what we refer to as management costs) and tree BVOC emissions (which we consider a disservice), and benefits reflected monetized estimates of ecosystem services such as building energy savings from shade, air pollution reduction, stormwater reduction, and increased housing prices (e.g., McPherson 1992, McPherson et al. 2005). In this way, early street tree ecosystem services studies were akin to return-on-investment analyses

**Table 2** Evaluation matrix for ecosystem services, disservices, and management costs in urban forests, adapted from Vaz et al. (2017). The potential governance responses are intended to maximize services while minimizing disservices, and list specific stakeholders involved. Scenarios align with flower diagrams in Fig. 4

| Scenario type | Example | Local context | Ecosystem services | Ecosystem disservices | Management costs | Potential governance response |
|---|---|---|---|---|---|---|
| Positive synergy | Well-maintained roadside green stormwater infrastructure sites with medium-stature trees | Temperate city with combined sewer system, commercial district, neighborhood at moderate risk of gentrification | Stormwater runoff reduction<br>Aesthetic appeal<br>Walkable streetscapes, promoting pedestrian traffic in commercial area<br>Carbon sequestration<br>Increased real estate values and rental prices | Minimal disservices, although installation and ongoing maintenance results in a modest amount of greenhouse gas emissions, and some neighbors may perceive trees as promoting gentrification | High installation costs for highly engineered sites<br>Seasonal maintenance | *Municipal public works dept.:* Sustain effective stormwater functions through seasonal maintenance, strategize techniques to lower greenhouse gas emissions from installation and maintenance, foster neighborhood dialogue to understand and counteract gentrification concerns |
| Tradeoff | Large non-native invasive residential yard trees | City with a Mediterranean climate, neighborhood near natural area | Shade for thermal comfort, building energy-use reduction, and emissions avoidance<br>Carbon sequestration from large-stature tree<br>Aesthetic appeal | Invading nearby natural areas, reducing wildlife habitat<br>Increased wildfire risk<br>Carbon emissions from installation<br>Infrastructure conflicts with overhead wires<br>Nuisance complaints from shedding bark or leaf litter | Routine risk management inspections to address infrastructure conflicts<br>Potential emergency costs due to storms or wildfires | *Municipal policy-makers, planners:* Develop policies, guidelines, and/or outreach to reduce disservices related to invasive trees and wildfire risk, coordinate with municipal foresters about best practices<br>*Residents:* Carefully weigh when removal and replacement of invasive trees becomes appropriate |
| Negative synergy | Recently planted street trees that have died | Subtropical city, working class neighborhood facing gentrification pressure | Minimal services, as trees died soon after planting, although during their brief life the trees may have provided some aesthetic appeal | Unkempt standing dead trees signify lack of care<br>Residents concerned about green gentrification<br>Residents resist future planting programs<br>Disposal of tree waste into landfills<br>Carbon emissions from installation | Sunk planting costs for trees that failed to survive | *Municipal park dept.:* Provide permits for tree removal if needed, develop program to re-use tree waste<br>*Residents, contract arborists:* Remove dead trees promptly<br>*Planting program:* For future plantings, develop close collaborations with community organizations to address gentrification concerns, and hire local youth for maintenance and job training |

used in restoration planning and conservation (Goldstein et al. 2008; Auerbach et al. 2014). However, most urban forest ecosystem services analyses since then have focused primarily on benefits; disservices and management costs are rarely mentioned (Roy et al. 2012).

## SERVICES, DISSERVICES, AND MANAGEEMENT COSTS IN DECISION-MAKING

As with natural resource management generally, urban forestry stakeholders confront multiple, often competing objectives as they try to optimize ecosystem services while minimizing ecosystem disservices and effectively allocating limited financial resources. The combination of services and disservices leads to tradeoffs and synergies. Figure 3 simplifies ecosystem services and disservices into a two-dimensional space to depict scenarios of positive synergies (high services, minimal disservices), tradeoffs (services and disservices have similar magnitudes), and negative synergies (high disservices, minimal services). Yet real-world circumstances require a multidimensional assessment of services and disservices (Dobbs et al. 2014; Soto et al. 2018; Tian et al. 2020). The relative impact of several services and disservices can be illustrated in flower diagrams (Foley et al. 2005; Gamfeldt et al. 2012). In

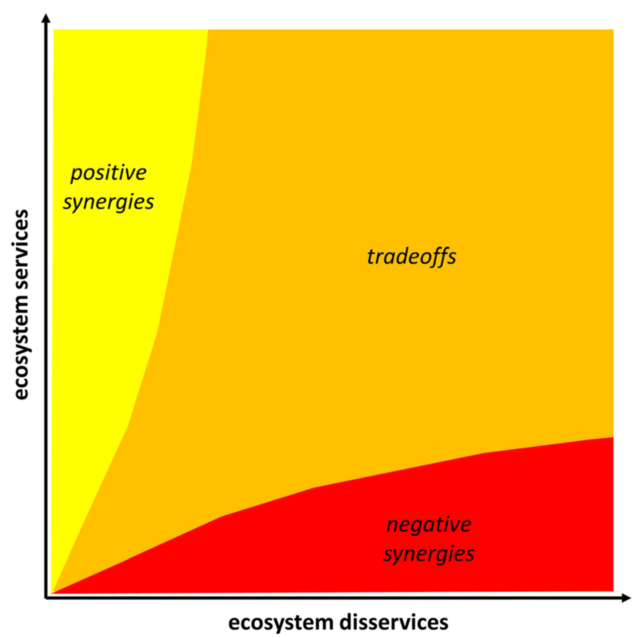


**Fig. 3** A simplified graph depicting scenarios of high and low ecosystem services and disservices. When ecosystem services are high and ecosystem disservices are low, there are positive synergies. Negative synergies result from circumstances when ecosystem disservices are high and ecosystem services are low. Tradeoffs arise when high ecosystem services are accompanied by high ecosystem disservices

Fig. 4, the length of each 'petal' reflects the magnitude of one particular service or disservice. The selection of services and disservices to depict in each flower diagram is subjective, and relates to stakeholder priorities in a particular locality. In an effort to layer management costs onto the visual depiction of tradeoffs and synergies, we also add cost considerations to the flower diagrams in Fig. 4. Furthermore, we suggest that careful consideration of ecosystem services, disservices, and management costs can point to productive governance responses (Vaz et al. 2017). Example scenarios discussed below are summarized in flower diagrams and an evaluation matrix (Fig. 4; Table 2).

### Positive synergies

*Positive synergies* are win–win scenarios in which multiple services are increased while disservices are reduced. Positive synergies generally imply circumstances in which the holistic impact is greater than sum of each individual component (Jackson and Mathews 2011; Table 1). Urban green infrastructure programs have been broadly framed as simultaneously achieving economic, social, and environmental benefits (Fitzgerald and Laufer 2017), reflecting expectations for positive synergies. Positive synergies are sometimes presented through the lens of co-benefits: a program that targets one particular ecosystem service (e.g., stormwater runoff reduction) is concurrently expected to produce other benefits (e.g., aesthetic improvements, increased real estate prices, Irwin et al. 2017).

While our paper has focused on the negative impacts of urban trees, positive synergies can and do occur. For example, a neighborhood tree planting program with paid youth staff carrying out maintenance can boost tree survival and growth while also providing job training to underserved communities (Roman et al. 2015). Such a program could lead to increased social cohesion and more walkable streetscapes (Roy et al. 2012). Sites with trees serving as green infrastructure to reduce stormwater runoff are another example of positive synergies (Berland et al. 2017). With such sites regularly maintained and functioning as intended, there could be reduced complaints from residents about tree litter, meaning that ecosystem services are increasing while nuisance-based ecosystem services are decreasing. Continuous maintenance (and associated management costs to stakeholders) is needed to sustain the win–win outcomes (Table 2).

While positive synergies may be possible, they are far from guaranteed. Ecosystem services that are presented as part of a win–win scenario may be coupled with disservices, leading to tradeoffs. For instance, increases in real estate values or rental prices (a service, Roy et al. 2012) can produce green gentrification (a disservice, Pearsall and Eller 2020). Low-income residents may decline to

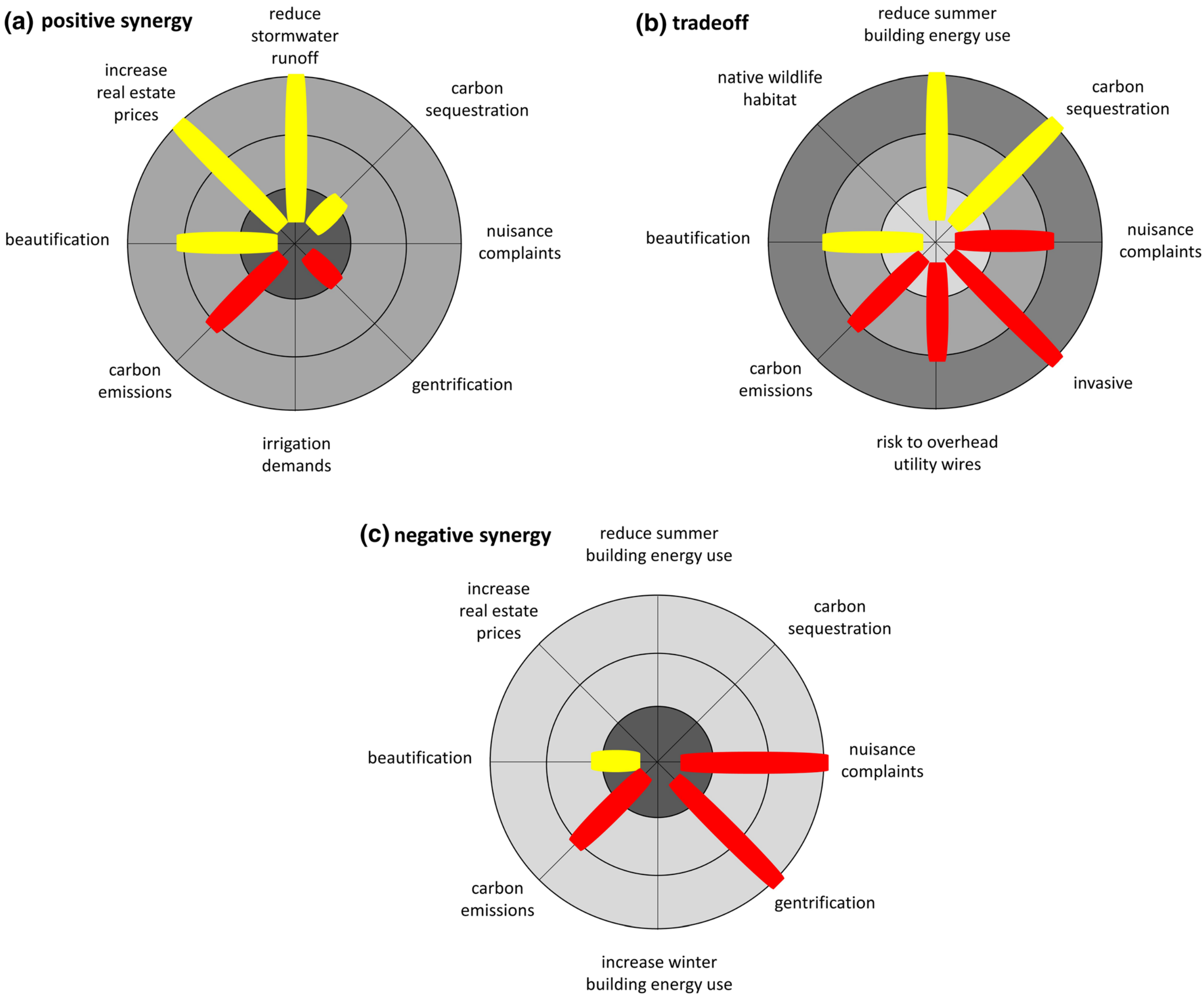


**Fig. 4** Flower diagrams depicting scenarios with multiple ecosystem services (yellow) and disservices (red) for urban trees. The length of each 'petal' reflects the relative magnitude of each service or disservice. Scenarios with far more services than disservices are positive synergies (**a**), while similar levels of services and disservices are tradeoffs (**b**), and far higher levels of disservices compared to services are negative synergies (**c**). The grey circles reflect management costs, with dark grey indicating higher costs. The inner-most circle represents installation costs, medium circle short-term maintenance, and large circle long-term maintenance. See Table 2 for more details

participate in greening programs due to gentrification concerns (Battaglia et al. 2014). Assuming that boosting real estate values is an exclusively 'good' outcome may have unintended consequences for the low-income, low-canopy neighborhoods targeted by some tree planting programs (Nguyen et al. 2017). Furthermore, even well-functioning green stormwater infrastructure sites involve some greenhouse gas emissions from the installation process. Yet if these disservices are modest relative to services, the scenario may still be considered a positive synergy (Fig. 4a). Potential governance responses to minimize these disservices include devising strategies to lower greenhouse gas emissions and fostering dialogue with communities to understand and counteract gentrification concerns (Table 2).

## Tradeoffs

Win–win scenarios do not capture the complexities of competing, rather than complementary, priorities (Howe et al. 2014). We suggest that *tradeoffs* may be more common than positive synergies, and thus tradeoffs take up the most space in Fig. 3 (see Persha et al. 2011, in which tradeoffs were 60% of forest conservation cases). The concept of tradeoffs (Howe et al. 2014; Turkelboom et al. 2018; Table 1) reflects the reality that optimizing one particular ecosystem service could (a) reduce other benefits, (b) increase undesirable disservices, or (c) both a and b. Prior research into tradeoffs has often focused on the situation in which increases in one ecosystem service is coupled with decreases in another service (case a, e.g., Howe et al. 2014, Felipe-Lucia et al. 2015). We primarily focus here on tradeoffs between services and disservices (case b, which is shown in Fig. 3), and argue that such tradeoffs represent win-lose scenarios, in which ecosystem services and disservices can both be large, and may increase or decrease in tandem.

Tradeoffs between services and disservices are tied to specific management practices, planting locations, and bioregional context. For example, if building cooling and carbon sequestration are the services prioritized by a planting program, then only large-stature trees that survive for several decades will produce those benefits (Ko et al. 2015; Petri et al. 2016). But the ecosystem services provided by large trees near buildings are inherently coupled with disservices, including conflicts with grey infrastructure (Fig. 4b). Furthermore, the capacity of trees to reduce residential energy usage depends upon climate, heating and cooling systems, and building type (Ko 2018, Erker and Townsend 2019), and the net effectiveness of urban trees for carbon sequestration depends upon planting, pruning, and disposal practices (Petri et al. 2016). Erker and Townsend (2019) found that trees increase building carbon emissions for cities located in cool climates due to increased heating in winter months. The authors argued that prior research into energy-saving benefits of urban trees originated in cities located in year-round warm climates, therefore the extension of that research into other climates can lead to inappropriate conclusions about the benefits of tree planting programs for energy-savings and emissions avoidance. There are under-appreciated tradeoffs regarding urban trees and building energy use in cool climates.

Furthermore, while municipal goals might center on promoting environmental benefits, or preventing safety-related disservices, some residents' attitudes are based on aesthetic services (Locke et al. 2015; Dronova 2019). For yard and street planting programs, many residents prefer small, short-lived flowering and fruiting trees for their beauty, nourishment, and cultural values, and some greening programs have shifted to distributing such trees even though they do not align with priorities to maximize environmental benefits (Locke et al. 2015; Conway 2016; Nguyen et al. 2017). Deciding whether a residential or sidewalk planting space should have a large-stature species versus small-stature species illuminates species selection tradeoffs. There are at least three competing goals with respect to selecting trees based on their expected mature size: (a) promoting cultural ecosystem services that address residents' preferences (with some preferring small ornamental trees), (b) long-term program objectives for the accrual of environmental benefits as trees mature (which requires large-stature species), and (c) lowering disservices by reducing risks to overhead wires (using small species). Importantly, species selection in planting programs cannot simultaneously address all three goals, making tradeoffs inevitable (Nguyen et al. 2017).

Decisions about whether to plant non-native species also involves tradeoffs between priorities to provide services and avoid disservices. Urban forest management plans in Southern Ontario have unresolved tensions between priorities for ecosystem services provisioning and promoting native species (Conway et al. 2019). A specific example of tradeoffs related to non-native species in an urban park is a *Pyrus calleryana* tree that survived terrorist attacks on the grounds of the World Trade Center in New York City (McMillen et al. 2019). This tree became a powerful social symbol of resilience (an ecosystem service), and was propagated by local urban foresters despite their concerns with this species' invasive properties (a disservice).

Species selection and planting decisions are particularly fraught for cities in arid and semi-arid climates, where irrigation is especially vital for the survival of recently planted trees. This problematizes tree planting campaigns and ambitious canopy cover goals in arid cities (Pincetl et al. 2013). Identifying tree species with low water demand and optimizing irrigation strategies can minimize the environmental resource requirements of tree maintenance (Revelli and Porporato 2018). Water scarcity issues in arid and semi-arid cities may become exacerbated with climate change, making drought-tolerant species selection even more critical (McPherson et al. 2018).

Urbanized landscapes in dry climates can also be subject to substantial forest fires, and trees intensify fire risk at the wildland-urban interface (Radeloff et al. 2018). Limiting vegetation near buildings reduces wildfire risks to homeowners, yet this practice conflicts with goals to expand tree canopy. The same individual tree (e.g., an invasive *Eucalyptus* sp. in a dry climate city) can simultaneously be viewed as producing both ecosystem services (e.g., beauty, cultural values, shade) and disservices (e.g., fire risk, alteration of native habitat, water demand), depending upon context (Potgieter et al. 2019; Teixeira et al. 2019). Decisions about what trees to plant and where to plant them, or whether to plant at all, are therefore tied to geographically local conditions and tradeoffs. To address these challenges, municipal foresters and planners can improve coordination to develop planting guidelines and outreach materials related to wildfire and invasive species (Table 2). Tradeoffs research in urban forestry has grown more sophisticated in the past few years (Dobbs et al. 2014; Soto et al. 2018), and more in-depth tradeoff studies are needed to inform policy and management.

### Negative synergies

In urban forestry scholarship, *negative synergies* have been largely ignored. We define negative synergies as lose–lose scenarios in which disservices are exacerbated while ecosystem services are reduced, and the negative impacts compound (Jackson and Mathews 2011; Persha et al. 2011; Zhou et al. 2018; Table 1). An example of negative synergy is when recently planted trees die from insufficient maintenance and fail to survive to maturity when environmental benefits are greatest (Ko et al. 2015; Petri et al. 2016). Such dead trees require carbon and other greenhouse gas emissions to install but do not endure long enough to provide carbon sequestration benefits (Fig. 4c). While there may be a brief period of aesthetic appeal from newly planted trees, once the trees are dead, they can contribute to landscape disorder and reflect poorly on the local community (Breger et al. 2019). This is not a minor issue: based on a recent review of urban tree mortality, 30% of trees typically die within five years after planting, and 50% are dead by 13-18 years (Hilbert et al. 2019). When planted trees die while relatively young, they represent sunk management costs (Nguyen et al. 2017), and dead trees will not provide the long-term environmental benefits sought by planting programs. The problem of young tree mortality often results from lack of maintenance (Roman et al. 2014; Vogt et al. 2015; Breger et al. 2019), and can also be linked to species selection and planting stock (Roman et al. 2014; Allen et al. 2017). Trees that were recently planted and died from inadequate maintenance can, therefore, be viewed as a consequence of decision-making that does not support the resources, staffing, and stewardship networks necessarily for young tree care (Roman et al. 2014, 2015; Breger et al. 2019). Trees that die from lack of maintenance can even make residents resistant to planting programs (Carmichael and McDonough 2019), compounding the negative impacts of tree death. To ameliorate the problems associated with young standing dead trees, municipal foresters can promptly remove them, and for future plantings, consider community collaborations and youth jobs programs that promote maintenance and stewardship (Roman et al. 2015; Table 2).

Once removed, dead street and lawn trees are disposed of in various ways: chipped into mulch for reuse in the community, milled for timber, or sent to a landfill, with the latter outcome leading to the most greenhouse gas emissions (Petri et al. 2016, Aruájo et al. 2018). Dead trees in forested natural areas (both urban and rural) provide critical biodiversity habitat (Stokland et al. 2012); standing dead street trees are a physical hazard and an aesthetic eyesore. When removed urban trees are used as productive wood products, those trees are providing an ecosystem service, but when they are sent to a landfill, it is an ecosystem disservice.

## SERVICES AND DISSERVICES ARE ROOTED IN PEOPLE'S PERCEPTIONS

Vaz et al. (2017) asserted that the biophysical attributes and functions (e.g., biodiversity, nutrient cycles) that underlie ecosystem services and disservices are 'value-free', and human perceptions determine whether people see particular situations as providing services, disservices, or both. In other words, perceptions about ecosystem services and disservices are highly subjective. Perceptions about urban trees are not monolithic and are expressed in various ways, such as attitudes, preferences, beliefs, and values. Attitudes and preferences are related to how people like or prefer something (Heberlein 2012), while beliefs are more stable ideas people have about the positive or negative aspects of something. Whether people like or dislike trees in specific situations can vary widely depending on the situation and people's demographic backgrounds (Jones et al. 2013). Common beliefs about trees include positive aspects such as shading and beautification (Lohr et al. 2004; Kirkpatrick et al. 2012), and negative aspects such fire risk and damage to grey infrastructure (Kirkpatrick et al. 2013; Conway 2016; Tian et al. 2020). While beliefs are more stable opinions, they can also vary in terms of context, such as the placement of specific trees and people's personal experiences with trees (Kirkpatrick et al. 2013; Conway and Yip 2016). Finally, values can be understood as what people consider important (Rokeach 1973). Values are normative, positive statements about how people assign importance to nature (Dietz et al. 2005), including urban trees (Ordóñez and Duinker 2014). While most people value urban trees and believe positive things about them, some people may still hold variable attitudes and preferences about specific trees in specific situations, or even believe negative things about trees. For example, in contexts with strong positive messaging about trees, such as in tree planting campaigns, when residents decline to plant trees, their behaviors can be construed as disliking or even hating trees (Kirkpatrick et al. 2013), rather than as a reasoned response about disservices. When we gloss over the detrimental impacts of urban trees, we fail to acknowledge the diversity and validity of people's opinions, and the reality that disservices do exist (Shackleton et al. 2016).

Understanding that people's perceptions of trees are complex and varied can help us to interrogate the 'trees are good' mantra and related statements in a constructive manner. The generic declaration that 'everybody loves trees' may work well with some audiences for awareness-raising and advocacy purposes, but it also implies normative beliefs about trees and homogenizes the diversity of people's opinions (Braverman 2008; Ordóñez et al. 2017). The fact is that not all urban forest stakeholders hold positive opinions about all trees in all situations, and people are motivated by different attitudes, preferences, or beliefs (Braverman 2008; Kirkpatrick et al. 2013; Battaglia et al. 2014; Conway 2016; Carmichael and McDonough 2019). As such, tree-related perceptions of different individuals and across diverse communities lead to different ecosystem services and disservices tradeoff decisions, depending on the stakeholders involved and the particular local circumstances.

## CONCLUSIONS

Research that integrates services, disservices, and management costs could better inform urban forest policy and management. Additional studies across a range of ecological and sociopolitical conditions are needed because local context matters. Much of the existing urban forestry research comes from industrialized, developed countries, and may not translate well to urban areas in developing countries, due to differences such as urbanization patterns, socioeconomic inequalities, and weak environmental governance (Shackleton 2012; Dobbs et al. 2019). Variation in bioregional contexts and financial resources for proactive urban forest management, even within developed countries (Hauer and Peterson 2016; Erker and Townsend 2019), suggests a fundamental need for empirical studies across a range of socioecological conditions. Diligent evaluation of tradeoffs and synergies can help in the analysis of competing priorities across a diverse array of stakeholders and in a wide range of localities. The decision-making process can respond to both local environmental conditions and sociocultural context, bringing nuanced perspectives that reflect stakeholder opinions. Our evaluation matrix (Table 2) and flower diagrams (Fig. 4) offer a first-order attempt to integrate differing services, disservices, and costs for example urban tree scenarios. More quantitative and qualitative studies are needed to compare and contrast empirical data about services, disservices, and costs across localities.

Based on the arguments raised in this article, we suggest that researchers studying urban trees should consider investigating the following topics:

- Quantitative life cycle assessments that account for positive and negative environmental impacts, as well as management costs, throughout the life of a tree (and systems of trees), and projections of disservices under changing future conditions (e.g., related to climate change).
- Qualitative analyses of ecosystem disservices, as experienced by arborists, residents, and other stakeholders, and how their perceptions relate to their attitudes, preferences, and beliefs.
- Evaluations of tradeoffs and synergies (both positive and negative) in urban forestry decision-making, particularly the extent to which stakeholders simultaneously recognize the ‘good’ and ‘bad’ aspects of urban trees, and how stakeholders weigh ecosystem services and disservices.
- Return-on-investment and cost-effectiveness analyses to evaluate divergent scenarios for ecosystem services and disservices of urban trees, depending upon different budgetary allocations and management strategies.
- Content analyses regarding services and disservices in urban greening and urban forestry advocacy materials and media coverage (print, broadcast, online, and social), including both contemporary and historical sources, to understand how services/disservices have been framed in different sectors and over time.

By voicing concerns about the ‘trees are good’ mantra, we might be seen as hurting the cause of urban greening. That is not our intention. We can support urban forestry programs while drawing attention to shortcomings of the dominant discourse, recognizing that managing sustainable urban landscapes requires strategies to address inevitable tradeoffs and potential negative outcomes. Although some disservices can be minimized through best management practices, there are unavoidable negative impacts from city trees. For instance, the only way to completely eliminate tree-related injuries and grey infrastructure damage is to have no trees near pedestrians and built structures. We are clearly not in favor of that outcome, but we must acknowledge that services are often accompanied by disservices. Without recognizing the disservices associated with urban trees, planting programs may not meet sustainability goals and could yield unintended consequences, such as exacerbating water shortages or provoking gentrification concerns. Indeed, productive studies into the topics listed above will require convergence research featuring deep interdisciplinary and transdisciplinary integration that embraces epistemological pluralism, with urban forestry practitioners as central partners (Campbell et al. 2016; Eisenman et al. 2019). We call for scholarship on urban trees to take an integrated approach to socioecological sustainability that addresses the complexities of competing and compounding interactions among services, disservices, management costs, and differing perceptions among and within stakeholder groups.

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