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Short communication

Including public-health benefits of trees in urban-forestry decision making

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ABSTRACT

Research demonstrating the biophysical benefits of urban trees are often used to justify investments in urban forestry. Far less emphasis, however, is placed on the non-bio-physical benefits such as improvements in public health. Indeed, the public-health benefits of trees may be significantly larger than the biophysical benefits, and, therefore, failure to account for the public-health benefits of trees may lead to underinvestment in urban forestry. In addition, the distribution of trees that maximizes bio-physical benefits may not maximize public-health benefits.

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Research quantifying the biophysical benefits of urban trees is often used to justify investment in urban-forestry programs. For example, in documentation supporting their million-tree initiative, New York City's Department of Parks and Recreation list five categories of urban tree benefits (Peper et al., 2007). The first four categories are biophysical: energy savings, carbon sequestration, improved air quality, and storm-water management. It is only the final catchall category that includes non-biophysical benefits. These five categories of benefits are also used to support the Los Angeles million-tree initiative (McPherson et al., 2008).

However, in focusing on the biophysical benefits of trees, urban foresters may be failing to account for important non-biophysical benefits such as reduced crime and, in particular, improved public health. For convenience, I will refer to the non-biophysical benefits, crime reduction and improved health, as social benefits (note that while improved health and reduced crime are social benefits of trees, they are not the only social benefits that trees provide). Not giving adequate weight to the social benefits of trees may not only underestimate the total value of trees, it may also lead to inefficiently designed urban-forestry programs.

It is not surprising that cities invoke the biophysical benefits of trees to support urban-forestry programs, as these benefits are intuitively easy to understand. Most people have enjoyed the shade of a tree on a hot day or seen leaves intercept raindrops before they hit the ground. Biophysical benefits can also be relatively straightforward to quantify. For example, if you can estimate the pollution interception of a single leaf, then this estimate can be scaled up to calculate how much pollution a tree intercepts (Nowak et al., 2006). Several computer models, most notably i-Tree, use this approach to estimate the biophysical benefits of trees.

In contrast, the social benefits of trees can be less intuitive and more difficult to measure, which may be problematic, as research from other fields has repeatedly shown that easily measured benefits are overemphasized in decision making (Altbach, 2015 McIntosh and Macario, 2009).

The purpose of this paper is to examine the relative importance of two biophysical benefits (reduced residential heating and cooling costs, and reduced storm-water management costs) and two social benefits (improved public health and crime reduction). In addition, I will explore the consequences for urban-forestry policy of correcting for an overemphasis on the biophysical benefits of urban trees.

I chose these four benefits, because research has repeatedly identified them as important urban-forestry benefits (Akbari et al., 1997; Asadian and Weiler, 2009; Donovan et al., 2011; Kuo and Sullivan, 2001). In addition, these four benefits largely manifest as avoided costs (avoided costs can be financial, but they can also include non-financial costs such as reduced quality of life). For example, if a tree cools a house on a hot day, then the homeowner will spend less on air conditioning. Focusing on avoided costs is useful, because there is insufficient information to directly compare the public-health, storm-water management, heating-and-cooling, and crime-prevention benefits of urban trees. However, the magnitude of these four cost categories offers some insight into the magnitude of benefits, because total costs are an upper bound on

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each category of urban-tree benefits. For example, the storm-water benefits of urban trees cannot exceed the total cost of storm-water management in the US. It follows that if total costs are higher, then the potential for urban tree benefits is also higher.

1. Healthcare, crime, storm-water, and energy costs

In 2014, US healthcare expenditures were $3.0 trillion (Centers for Medicare and Medicaid Services, 2014). For comparison, the US gross domestic product in 2014 was $17.3 trillion (World Bank, 2016).

McCollister et al. (2010) estimate that, in 2007, crime in the US imposed $15 billion in direct economic costs on victims. In addition, government spent $179 billion on the criminal justice system. Adjusting these costs into 2014 dollars using the consumer price index gives a total cost of $222 billion.

The National Association of Clean Water Agencies (2013) estimates that the annual average sewer-service charge in the US was $435 per household in 2013. They note that average sewer charges rose 5.5% from 2012 to 2013. Assuming the same rate of change from 2013 to 2014, the 2014 mean sewer-service charge would be $459. The US Census (2014) estimates that there were 123,229,000 households in the US in 2014, so total sewer-service charges in 2014 were $57 billion.

In 2014, the total cost of residential heating and cooling was $134 billion (US Energy Information Administration, 2016). I calculated this number using consumption and price data for electricity, natural gas, fuel oil, and propane. For each energy category, I calculated total cost by multiplying total use by per-unit cost.

Health-care costs dwarf the three other cost categories. However, this doesn't mean that public-health is the largest urban-tree benefit, because we don't know the marginal effect of trees on the four cost categories. Nonetheless, even a modest proportional reduction in healthcare costs would result in large absolute costs savings. Furthermore, it is unlikely that reductions in crime, energy use, or storm-water costs could match these cost savings (Wolf et al., 2015). For example, to match a 1-percent reduction in healthcare costs ($30 billion), crime would need to decline by 14 percent, residential heating-and-cooling costs by 22 percent, and storm-water management costs by 53%.

Note that urban trees are not the only part of the natural environment that generate public-health benefits. For example, research has shown that exposure to parks (Cohen et al., 2007) and gardens (Sherman et al., 2005) is also associated with improved wellbeing. However, determining the health benefits of different components of the natural environment can be difficult, as these components often co-occur. Parks and gardens often contain trees, for example. Improvements in remote sensing may allow us decompose the health benefits of an urban landscape into its component parts. In turn, this decomposition may help design urban landscapes that maximize human health.

2. Policy implications of considering the public-health benefits of urban trees

If we accept, for the moment, the premise that the social benefits of trees (in particular the public-health benefits) are larger than the biophysical benefits, then there are two main implications for urban-forestry policy. First, and most simply, considering social benefits increase the total benefits of trees. Greater benefits can be used to justify increased investment in urban forestry. Second, the distribution of urban trees that would maximize the storm-water or energy-saving benefits of trees would not necessarily maximize the social benefits of trees. Therefore, considering social benefits could change the optimal location for tree planting and retention. To explore how considering the public-health benefits of trees might affect the optimal distribution of urban trees, let us consider how tree distribution affects storm-water, energy use, and public health (we focus on the larger social benefit, public health, to make the comparison more straightforward).

Cities are increasingly using trees and other green infrastructure to help manage storm-water (Day et al., 2008; Xiao et al., 1998). In particular, urban trees are being used to address the challenges posed by large areas of impervious surface. When rain falls on impervious surface, it quickly flows into the storm-water system. This surge of storm-water can overwhelm the capacity of pipes leading to overflows into rivers and backups for residential and commercial customers (Villarreal et al., 2004). The consequence of these overflows is more severe in communities with a combined sewer system in which sanitary flow and storm-water share a single system of pipes. Trees can intercept rainwater before it enters the storm-water system. This interception is especially beneficial, if the tree canopy is covering impervious surface.

Trees can also help reduce energy consumption. In particular, trees close to a house can reduce summertime cooling costs. In addition to proximity, orientation matters. Trees to the west and south of a house have the biggest impact on cooling costs (Donovan and Butry, 2009).

To understand how tree distribution could affect public health, it is instructive to consider four mechanisms that could link trees and health: improved air quality, reduced stress, increased exercise, and improved social connections (Hystad et al., 2014).

Trees in areas with high population density and high air pollution will provide the greatest health benefits from improved air quality, because the dose-response functions linking air pollution and health are typically nonlinear—increments of air pollution have a progressively greater impact on health (Daniels et al., 2000). Therefore, all else equal, a tree in an area with high air pollution will have a greater impact on public health than the same tree in an area with lower air pollution. For example, planting trees along a freeway that runs through a residential area would be a good strategy to maximize the effect of trees on air pollution and, ultimately, public health.

Several studies have shown that people living in neighborhoods with greater access to parks and other greenspace exercise more (Coombes et al., 2010; Hansmann et al., 2007). Other studies have shown that increased greenness contributes to increased neighborhood walkability, which is associated with increased exercise (Frank et al., 2005; Lovasi et al., 2011). This suggests that, to encourage exercise, parks and public rights of way are the best location for trees.

A number of studies have found that increased access to greenspace, such as parks, is associated with reduced stress (Hartig and Staats, 2006; Roe and Aspinall, 2011; Stigsdotter et al., 2010; van den Berg et al., 2010). This suggests that, as with exercise promotion, access to continuous areas of greenspace can help reduce stress. Not all studies have focused on access to greenspace. Ward Thompson et al. (2012) found that increased greenness around a person's home was associated with lower levels of the stress hormone cortisol. Other studies, focusing on health outcomes rather than stress reduction, have found a relationship between residential greenness and improved health. For example, two separate studies found that women with more greenness within 50 m of their homes were less likely to have underweight babies (Donovan et al., 2011; Laurent et al., 2013).

There has been less research on the link between greenness and social connectivity. Nonetheless, research has shown that increased access to greenspace is associated with reduced loneliness and an increased sense of community (Kim and Kaplan, 2004; Maas et al., 2009). As with exercise and stress reduction, concentrated areas of