The Public Good Nature of the Urban Forest and Implications for Management

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Abstract: This paper uses the context of the urban forest to illustrate how identifying the nature of goods yields important implications for the management of natural resources.
Urban trees provide an array of economic, social and environmental benefits, yet canopy cover in cities in the United States is frequently lower than desired and often decreasing. Given the public benefits of urban trees, some scholars have referred to urban trees as a public good. However, little work has given the discussion more than a few sentences and scholars disagree over the "nature of the good" for urban trees. Even less work has connected the public goods nature of the urban forest to the challenges of urban forest management or used it to inform evaluation of policy tools for urban forest management. This paper lays out the argument that the urban forest is best considered as a public good, rather than as a common pool resource. It then illustrates the implications of this argument for the health of the urban forest—without public intervention, there are fewer urban trees than is socially optimal. Finally, it discusses the implications of this argument for urban forest management, including a discussion of policy tools most suited to encourage tree planting and care. It concludes that two options offer opportunities to increase both public and private trees: grants to and coproduction with residents in planting and maintenance activities.

1.0 INTRODUCTION

Urban trees provide an array of local and global benefits (i.e. ecosystem services), including benefits to the environment, to public health and to communities. Yet, urban forests have declined in many cities in the last few decades and urban canopy cover in many cities is below recommendations or targets (Nowak & Greenfield, 2012). Properly identifying "the nature of a good" is important to selecting appropriate strategies to address environmental problems (Gibson et al. 2000). Previous work in urban forestry has briefly mentioned the nature of the good (e.g., see Mincey et al. 2013), but there is disagreement among scholars whether components of the urban forest are public goods or common pool resources. Additionally, little work has given the discussion more than a few sentences (see Fischer & Steed 2008 for an exception). Even less work has connected the public goods nature of the urban forest to the challenges of urban forest management or used it to inform evaluation of policy tools for urban forest management.

This paper lays out a more thorough treatment of the "nature of the good" question and demonstrate how an understanding of the nature of the good can inform management. Along the way, it seeks to clarify concepts and terms that have been inconsistently used in the literature and considers the extent to which we can draw on previous research in rural forests to understand management in urban forests. By examining the kinds of ecosystem services that urban forests provide (discussed in this introduction), Section 2.0 argues that the urban forest is best considered as a multi-faceted public good. The paper then draws some implications of this argument for the structure and function of the urban forest in Section 3.0—without public intervention, there are fewer urban trees than is socially optimal. Cities across the United States vary dramatically to the extent and manner in which they manage and regulate the urban forest (Profous & Loeb, 1990). Section 4.0 discusses policy tools for urban forest management and comment on their suitability in light of the discussion in section 3.0 and of the particular characteristics of the urban forest.

Defining the urban forest

Before tackling the "nature of the good," this section defines the urban forest and its components. Tyrväinen and Väänänen consider the urban forest "wooded areas located within town limits or close to town" (Tyrväinen & Väänänen, 1998, p. 117). Their definition includes forested parks, recreation areas and protected forests but explicitly excludes constructed parks (Tyrväinen & Väänänen, 1998) and also seems to exclude trees near streets and in yards. Strom (2007, p. 99) offers a more inclusive definition of the urban forest: "the land in and around areas of intensive human influence, ranging from communities to dense urban centers, which is occupied or potentially occupied by trees and associated natural resources." His definition includes land that is "planted or unplanted, used or unused, and includes public and private property and street, transportation and utility corridors" (Strom, 2007, p. 99). While Strom praises his definition for including potential future urban forests, this paper is concerned with the presence (and absence) of actual trees. The difference between planted and potentially planted land is significant. This paper considers the *urban forest* to be the land in and around areas of intensive human influence which is occupied by trees and associated natural resources. Frequently it refers to *urban trees*, the trees that are part of the urban forest.

Urban trees grow in a number of different urban land areas, including in parks and recreation areas; near waterways and other natural features; in remnant forests; in brownfields and abandoned properties; in private yards, and in public rights of way along streets. Strom (2007) argues that the distribution of the urban forest between private and public land dictates the kind of policy that will effectively protect and improve urban forest structure and function. Much early urban forestry research focused on street trees and to a lesser extent, park trees (Loeb, 1987). An estimated 90% of urban trees are on private land on average (Gerhold, 2007), and recent research has considered policy related to these trees (Donovan & Butry, 2010). Noting the ecological importance of trees on both types of land, and noting the policy importance of distinguishing between these types of trees, this paper focuses on both "public trees" (trees growing on public land) and "private trees" (trees growing on private land)—collectively, urban trees. There is no consensus on the definition of street trees so this paper

adopts a general definition used elsewhere (see Fischer and Steed 2008) and defines *street trees* to be those trees in cities that are located in close proximity to public streets. Street trees then, although commonly planted on public property, might be private or public trees.

The benefits and costs of urban trees

Benefits. Urban trees provide environmental, economic, health and social benefits (Peper, McPherson, Simpson, Vargas, & Xiao, 2009) at a number of scales. Trees can improve the local urban environment. They can filter particulate matter and other air pollutants to improve local air quality (Nowak 2006). They can intercept rain and help to reduce local flooding and can improve local water quality (Xiao, Mcpherson, Ustin, Grismer, & Simpson, 2000). Trees can also yield local economic benefits. Strategically planted trees can reduce cooling costs in summer by shading homes and reduce heating costs in winter by blocking cold winds (McPherson & Simpson, 2003). Trees have also been found to increase economic activity in urban business districts (Wolf, 2003), and to raise the value of both properties on which they are planted and of neighboring properties (Donovan & Butry, 2010).

Urban trees have been found to improve health and well-being of individuals nearby. One of the most often cited values of urban trees is their contributions to city appearance (aesthetic benefits). Trees can also benefit public health. For example, trees were found to reduce mental fatigue and to increase ability to cope with critical issues for poor residents in urban public housing (Kuo, 2001); to reduce levels of stress in deprived communities (Ward Thompson et al., 2012); and to hasten recovery time of hospital patients (Ulrich, 1984). Trees can also serve architectural and design functions like acting as a screen to block an unsightly view (Ingram, 2007; Lawrence, 1995).

At the city or regional level, trees provide significant environmental benefits, particularly in reducing urban temperatures and mitigating the urban heat island effect (Rosenzweig et al., 2006).

Globally, urban trees also serve as a sink for atmospheric carbon dioxide, and so contribute to climate change mitigation (Nowak & Crane, 2002).

Benefits of trees as ecosystem services. Some scholars refer to the benefits of urban trees and other environmental amenities as ecosystem services—"the benefits people obtain from ecosystems" (Mincey et al. 2013, Millenium Ecosystem Assessment, 2005 p. v). There are four primary types of ecosystem services: provisioning services (e.g. food, timber, water); regulating (e.g. climate regulation, water purification); supporting (e.g. nutrient cycling, photosynthesis), and cultural services (e.g. recreation, spiritual experience) (Millenium Ecosystem Assessment, 2005). If we characterize the benefits of urban trees according to this typology of ecosystem services, a clear pattern emerges. Although some urban trees provide food (i.e. fruit trees), and a few urban trees might be harvested for timber (or, for example, illegally cut for Christmas trees), few of the benefits of urban trees are provisioning ecosystem services. Urban trees are cultivated for aesthetics and environmental benefits, rather than timber (Gerhold, 2007) and so they provide mostly regulating and cultural services. City and nonprofit urban forestry programs cite these regulating and cultural services when justifying tree planting and maintenance activities.[1]

Costs. There are three primary costs of urban trees: they are expensive to plant, maintain and remove; they can be a nuisance, and they have opportunity costs.

The urban forest is not naturally regenerating—the majority of urban trees must be planted, rather than sprout naturally (Neville, 2007). This is particularly the case for street trees. Tree planting can be costly in time and financial resources (Blair, 2007; Peper et al., 2009). For newly planted trees to survive in harsh urban environments, they require proper maintenance and care, which include watering, pruning and mulching (Vogt, Watkins, Mincey, Patterson, & Fischer, 2015). Mature trees require routine pruning (Peper et al., 2009). Finally, trees are also costly to remove (Blair, 2007).

Urban trees can also be a nuisance. Tree litter like leaves, seed pods, fruit and flowers can make a mess particularly when trees are planted next to or grow over sidewalks and driveways (Gerhold & Porter, 2007). Trees can cause personal injury or property damage (Smiley,

[1] www.milliontreesnyc.org; www.kibi.org

Fraedrich, & Fengler, 2007); limbs can fall onto homes and vehicles (Smiley et al., 2007), limbs interfere with above-ground utility lines (Lee & Wolowicz, 2007), and roots disrupt sidewalks and underground utility systems (Comery, 2007). Certain tree genera like *Eucalyptus* spp. and *Quercus* spp. (Oaks) emit volatile organic compounds (VOCs) into the atmosphere, which contribute to ozone formation in the lower atmosphere (smog) (Nowak & Dwyer, 2007). Although increased urban vegetation might improve city-wide air quality, local effects can be positive or negative (Nowak & Dwyer, 2007). Trees can also produce allergens (Nowak & Dwyer, 2007) and although trees promote biodiversity by providing habitat, birds and squirrels are not always welcome neighbors.

Trees also have opportunity costs. A tree planted on the sidewalk takes up space that could otherwise be used for a bench or garden or widened street. Wooded parks could otherwise be business establishments or homes. Generally, planting a tree precludes that area from other use or development (Fischer & Steed, 2008).

Comparing benefits and costs: differences in scale

Many articles published in urban forestry describe a litany of benefits from urban trees but leave the costs of those trees to an aside or footnote. But the costs of urban trees are real and often substantial. Understanding the costs of urban trees and how they compare to the benefits is important in making decisions about urban forest growth and management.

One key distinction between the benefits and costs of urban trees is that of scale. Many of the costs (e.g. planting and maintenance; property damage) are site specific and accrue to the property owner or nearest neighbor. The benefits of trees are experienced more broadly. The carbon storage urban trees provide is perhaps the most diffuse—it yields global benefits). Urban heat island mitigation can benefit residents across the city. Even local benefits like aesthetics are experienced by neighbors and passersby. Few benefits that urban trees (even private trees) provide are experienced only by the tree owner. This difference between who experiences the benefits and the costs of urban trees is significant to the provision of the urban forest discussed below in Section 3.0.

2.0 THE URBAN FOREST AS A PUBLIC GOOD

Economic theory can provide some insights about urban forests. The next section argues that the urban forest can best be considered a public good.

A taxonomy of goods

Using a simple and common taxonomy, goods can be sorted along two basic characteristics of their consumption: rivalry and excludability. If a good is rival in consumption, one individual's use of the good will reduce the availability of the good for other potential beneficiaries. If a good is excludable, an individual is able to exclude others from the use or benefit of the good. Goods that are both rival and excludable are considered private goods (e.g. bread). Goods that are neither rival nor excludable are considered public goods (e.g. television airwaves, gardens). Goods that are rival but that are also nonexcludable, are called common pool resources (e.g. rural forests). Conversely, goods that are nonrival but excludable are club goods.

The owner of a private good can prevent individuals from using the good. They can charge a price for access to the good or its benefits and, in other words, they can internalize the benefits of the good through market exchange. If a good is nonexcludable, it is available to all consumers whether they pay a price for it or not. In the case of public goods, "for a consumer to actually make a payment would be nothing more or less than an act of pure charity" (Davis & Whinston, 1967, p. 362). Without being able to charge a price, the owner has no way to capture the value of the benefits consumed by others (she cannot internalize them). These benefits are considered positive externalities.

Previous literature considers nature of the good

This paper is not the first to consider the nature of urban environmental amenities. Economists have offered gardens ("your nice garden is any passerby's nice view" (Bator, 1958 p. 370)) and urban parks (Weigher & Zerbst, 1973) as examples of public goods. Most relevant to this paper, scholars in urban forestry have mentioned the public goods nature of street trees (Mincey et al., 2013) and urban forests (Oleyar et al., 2008). However, there is no consensus. For example, Loeb argues that urban parks are common pool resources (1987). The most thorough treatment of the

nature of street trees is presented in a working paper by Fischer and Steed (2008) in which they argue that street trees are most appropriately considered common pool resources.

Nonrivalry and nonexcludability of urban forest benefits

Applying this taxonomy to types of ecosystem services, it is clear that provisioning services have a different nature than regulating and cultural services. Provisioning services are rival—consumption by one individual prevents others from consuming the same resource. For example, one user's harvesting of fruit prevents another user from harvesting the same fruit. Most regulating and cultural services are nonrival. No one individual's benefit from carbon sequestration of a forest influences another individual's benefit from carbon sequestration of that same forest. The same holds for aesthetic benefits, soil stabilization, and other similar services.

Most of the ecosystem services that urban trees provide are regulating and cultural services—benefits that are not easily excludable. A property owner cannot prevent his neighbors from experiencing improvements in air quality, street beautification or summer temperature reduction from his planted tree. Precisely, the planted tree on his property produces positive externalities that he cannot internalize. Occasionally, the benefits of trees are exclusive to the property owner, but commonly not or even many of them are. As is the case in urban forestry, generally most ecosystem services cannot or are not traded in markets (Lant, Ruhl, & Kraft, 2008). If most urban tree benefits are regulating and cultural services (nonexcludable benefits), then urban trees are not likely private or club goods; they are either common pool resources or public goods.

The distinguishing feature between a common pool resource and a public good is the extent to which the good is rival. If one's "consumption" of urban trees influences or reduces another user's "consumption" of urban trees, then they are rival goods; else, they are nonrival. The kinds of benefits that urban trees provide are mostly nonrival. One urban resident's benefit from lower summer temperatures does not reduce or inhibit another resident's benefit from those same lower temperatures. If one neighbor experiences reduced stress from a planted tree, it does not influence the extent to which the tree reduces stress of other neighbors. Having

established that the benefits from urban trees are primarily nonexcludable and nonrival, urban trees are clearly best classified as public goods.

Of course, the urban forest does not nicely fit into one of four simple boxes. Urban forests provide different services to an array of households, individuals and groups (Oleyar, Greve, Withey, & Bjorn, 2008) and each type of forest cover (e.g. street trees, park trees, private trees) provides different amenities to these different groups (Mansfield, Pattanayak, McDow, McDonald, & Halpin, 2005). This complexity is often the case with environmental resources so that they are a mix of types of goods (McKean, 2000). Furthermore, exclusion is very rarely impossible with resources (Bator, 1958). Borrowing an example from Bator, "a recluse can build a wall around his garden" (1958, p. 374) so the urban forest is not a "pure" public good, but rather a multi-dimensional public good (Oleyar et al., 2008).

"Nature of the good" versus property regimes

The designation made about the nature of a good is distinct from designations that stem from property rights. A thing that is private property is not necessarily a private good. A thing that is "common pool" is not necessarily "common property" (Lant et al., 2008). Property institutions created to address challenges in resource management are manipulatable. However, "the nature of the good is an inherent physical characteristic, not susceptible to manipulation by humans" (McKean, 2000). For example, humans can institute private property rights to users of a rural forest as a strategy to prevent over-extraction of a rivalrous good, however those rights do not change the inherent rivalrous nature of the forest.

This distinction between the nature of a good and the managing property rights regime is important in urban forestry. While it seems apparent that public trees provide public benefits, private trees do too. The owners of private trees cannot exclude neighbors and passersby from enjoying the benefits of urban heat island mitigation or anyone from the carbon sequestration of the tree—they have positive externalities. That trees might be on private land, and might be private property, does not imply that they are private goods.

One useful illustration is to consider the urban forest to be comprised of two parts: a stock and a flow. The "stock" is comprised of the physical trees; the "flow" is comprised of the benefits (i.e. ecosystem services) that flow from those trees. While private property rights might prevent individuals from accessing the stock of private trees, they do not prevent individuals from experiencing the flow of nonexcludable benefits from those trees. Therefore, even private trees have a high level of "publicness."

Fischer and Steed (2008) argue that although the benefits that street trees provide are public goods, the street trees themselves and the tree spaces in which they grow are common pool resources. To reach this conclusion, the authors consider the land on which street trees are planted, rather than the benefits provided. They argue that because the land faces many competing uses, street trees are subtractable (rival). However, the nature of the good is about benefits—a good is rivalrous when a user's enjoyment (consumption) of the benefits of a good limits another user's enjoyment of the benefits of the good.

One key component of Fischer and Steed's argument is that the areas in which street trees are planted face competing uses. Indeed, one major challenge to urban forest management is that often trees are removed in order to use the land for other activities or structures and potential planting spaces are occupied with other structures. While Fischer and Steed argue that these competing uses of land where trees could be planted change the nature of the good, this paper offers that competing uses of land can be considered merely opportunity costs of trees. In the case where trees are removed, the benefits of keeping those trees are outweighed by their opportunity cost (the forgone benefits of replacing them).

Why urban forests are distinct from rural forests

Many environmental and natural resources are common pool resources (Gibson et al. 2000 Introduction) and decades of theoretical and empirical research has examined challenges to managing common pool resources. In particular, rural forests are often classified as common pool resources (McKean, 2000) and it is tempting to apply the theory developed around these resources to other environmental problems. But there are several fundamental differences

between rural and urban forests that suggest applying theory developed around rural forests to urban forestry is ill-advised.

First, the nature of the benefits provided from rural and urban forests are different. Rural forests provide a mixture of rival and nonrival benefits and often they are managed for provisioning services like lumber and food that are rival in consumption. However, urban forests provide relatively more nonexcludable and nonrival benefits—they are primarily cultivated for aesthetic and environmental benefits (Gerhold, 2007).[2] Second, unlike rural forests, urban forests are not self-maintaining (Neville, 2007). That is, most trees in urban forests in the United States are planted intentionally. Few trees volunteer in the harsh urban environment and when they are it is a result of strategic choice to leave an area to regenerate. The challenge to urban forests does not come from too many users consuming too many rival forest resources, it comes from too few users providing tree planting, encouraging regeneration, and performing maintenance (see Section 3.0 for discussion of the management implications of this point).

3.0 MARKET FAILURE AND UNDER-PROVISION

Welfare economic theory suggests that the provision of public goods presents one case of market failure—the market "fails" to achieve social optimality. (Davis & Whinston, 1967). In a set of formative articles on a theory of public expenditure, Samuelson (1954, 1958; 1955; 1964) concludes that although we can define socially optimal levels of private and public goods (through some sort of voting or signaling strategy), rational individuals will not get to the socially optimal "bliss point" on their own ("by an invisible hand")(P. A. Samuelson, 1958). As a result, public goods are often underprovided (Davis & Whinston, 1967).

Urban trees provide positive externalities, so, while the owners of urban trees experience almost all of the costs of trees on their property (i.e. costs of planting, maintenance, removal, nuisances), they experience only some of the benefits. Without compensation for the public

[2] It is important to note the limits of dichotomy between the kinds of benefits rural and urban trees provide. For example, while tree poaching is not recently common in the United States, urban trees in developing countries are still harvested (Profous & Loeb, 1990). Similar pressure exists in some developed countries. For example, in Finland, city forests also serve as a source of timber (Tyrväinen & Väänänen, 1998).

benefits their trees provide, owners have little incentive to continue providing them. When owners decide how many trees they will have on their property, they will generally consider the private benefits they experience, and overlook the public benefits, and so the benefits of the urban forest will be underprovided.[3]

Evidence of under-provision

We cannot observe urban forests without modern property regimes and public interventions to know what the urban forest would look like in their absence. So we rely on theory to suggest that in the absence of public intervention, urban forests would be underprovided. However, empirical evidence from a number of strands of research suggests that current levels of the urban forest are lower than optimal and suggests urban forestry still faces the challenge of under-provision articulated above.

Several suggestions have been made for appropriate or optimal urban canopy cover and some evidence suggests current canopy cover is below those estimates. For example, in 1989, Moll reported that "urban forests are starving for trees" (1989, p. 61). A survey of streets in the United States revealed that about half of available planting spaces in the public right of way were without trees (Moll, 1989) and similar possibilities existed for planting in other locations like parks and yards. Moll predicted that the average city could double existing canopy (about 30%) to achieve maximum canopy cover of about 60% and furthermore expected this 60% to be "ideal tree cover" (Moll, 1989, p. 64). American Forests, a large nonprofit organization, recommends overall canopy cover of a minimum of 40% for cities in the Eastern, forested regions of the United States (Toronto, n.d.). There is evidence that average urban canopy cover does not meet this target. For example, Nowak and Greenfield (2012) estimated canopy cover in 18 cities across the United States and found an average of 28.4% land cover of trees and shrubs. Maximum canopy (as suggested by Moll 1989) might not be optimal canopy cover (Nowak et

[3] Lant and colleagues (2008) have articulated a similar phenomenon for ecosystem services, although they address mostly ecosystem services provided by rural ecosystems.

al., 2010) and neither suggested optimal is transparent in methods. Other research adds to the evidence that the urban forest is underprovided.

Consistent with assertions that tree canopy is below optimal levels, there are a few indicators that urban residents want more trees. For example, many cities have adopted tree canopy cover goals and strategies to increase canopy cover (City of Bowie, 2011; City of Virginia Beach, n.d.; Toronto, n.d.). Several surveys also reveal that urban residents want more trees. For example, a survey administered in Detroit revealed that, from a list of potential urban forest management practices (including tree maintenance and removal), tree planting was the most desired service of urban residents (Getz, Karow, & Kielbaso, 1982).

Finally, despite increasing popularity of and support for urban trees, there is evidence that the urban forest is in decline in many cities. The most comprehensive documentation of urban canopy cover in the United States was published by Nowak and Greenfield (2012). Nowak and Greenfield used photo-interpretation of digital aerial images to estimate canopy cover change in 20 cities in the United States for roughly five year periods in each city (during the mid to late 2000s). They found decreases in canopy cover in nineteen of those 20 cities and average annual loss in tree cover of 0.27 percentage points a year (in other words, about 0.9 percent of existing canopy cover was lost each year) (2012). The authors also used GoogleEarth to estimate change in canopy cover in all urban areas and found that about 4 million trees were being lost annually in urban areas of the United States. Other city specific studies have also documented decrease in urban forests. For example, the Baltimore-Washington area lost about 27 percent of its tree cover (from 51% to 37%) between 1973 and 1997.

Furthermore, there is evidence that preference for trees is higher than support for policy and activities that would increase trees which bolsters evidence that a market failure exists. In a study of residents in four Canadian neighborhoods, authors find that although respondents had a "nearly uniform desire" to live in a neighborhood with trees, their support was weaker for statements about common municipal policies that encourage tree planting and restrict removal (Conway & Bang, 2014).

Rural and urban forests

Section 2.0 established that rural and urban forests provide a different mix of goods and are managed for different types of goods. Urban forests are mostly managed to provide public goods, while rural forests are commonly managed to provide common pool resources. These different goods face different market failures. Because many services of rural forests are rival, an individual's use of the forest for those services (e.g. wood, food) reduces another individual's use of that forest. When there are many users that have access (i.e. in the absence of private property rights or other rules to limit/manage access), the forest becomes degraded, and so rival but non-excludable rural forests face a different market failure: the tragedy of the commons. When users recognize this is the case, theory says, they have an incentive to increase their use of the forest, seeking to capture as many resources as possible before the forest is depleted. In other words, concern about the condition of rural forests comes from *over-extraction* of rural forest resources, while concerns about the condition of urban forests come from *under-provision* of the forest.

Again, these are simple bifurcations to describe more complex linked human-environment systems. It is important to note that rural forests provide public goods (regulating and cultural ecosystem services) too, and over extraction of rural forest resources (provisioning services) leads to under provision of those public goods (Slee, 2006).

4.0 INTERVENTION

An understanding of the nature of the good, the associated market failure and particular characteristics of the resource helps reveal appropriate tools for resource management. Samuelson argues that identifying the nature of a good does not suggest immediately a certain kind of action (Davis & Whinston, 1967; Samuelson, 1964). However, it allows us to identify a certain set of tools available and to identify how successful these tools might be. This discussion of public goods and positive externalities suggests that leaving urban forestry to private individuals will not provide sufficient urban tree cover and suggests a role for public entities.

Still, in this case, identifying urban forests as public goods does not immediately imply that public provision is the appropriate or only strategy to increase canopy cover.

In their hedonic pricing study of street trees in Portland, Oregon, Donovan and Butry find that street trees not only increase the sale price of the property it is in front of, but also the sale price of neighboring properties (Donovan & Butry, 2010). They conclude that in Portland, where residents are responsible for the provision and maintenance of street trees, the city should bear more of the costs because street trees will be underprovided otherwise (Donovan & Butry, 2010). But the city could undertake any number of strategies that increase the costs it bears. For example, the city can provide the good directly; it can contract with private or nonprofit organizations to do so, it can assign property rights and responsibilities, and/or it can incentivize and regulate behavior of individual city residents. Finally, it can partner with residents and non-profit organizations to co-produce the urban forest.

Additionally, urban forests are complex in the benefits they provide; in the types of land (e.g. street lawns, brownfields, yards) on which they grow; in the property regimes that govern that land; in the activities required for their health (e.g. planting, maintenance, removal), and in the actors that benefit from, manage and own urban trees. This complexity suggests that a single strategy for urban tree management will be insufficient. Municipalities have implemented a variety of strategies to protect and care for existing trees and to encourage growth through planting and allowing regeneration, but in many cities in the United States, urban tree canopy cover is still lower than socially optimal, which suggests that current strategies are not sufficient or effective. Empirical research on the effectiveness of institutions is minimal (Mincey et al., 2013). Recognizing that urban trees provide non-rival, non-excludable benefits suggests some strategies in some contexts might be more effective than others. Considering the particular nature of the urban forest yields more insights in appropriate tools for management.

In addition to the characteristics of the urban forest discussed above, there are several other features of the urban forest that are important when considering management options. First, tree care requires expertise, labor, and physical equipment. Second, the urban forest is an interconnected resource. Public trees in a city park are part of the same ecosystem as private

trees in a yard nearby or regenerated trees in a brownfield across the city. Comprehensive management of urban forests considers the urban forest as an ecosystem rather than an unrelated set of individual trees (Nowak et al., 2010).

This section describes a number of potential strategies for addressing public goods problems: public provision, property rights, regulation, and coproduction. For each strategy, this section provides examples of its use in urban forestry and discusses its strengths and limitations in the context of urban forestry. In the United States, tree policy is mostly the responsibility of local governments (Profous & Loeb, 1990), so this section will focus on strategies at the city or municipal level. Nonprofit organizations are increasingly involved in urban forestry and are often the primary management agent in some cities, so city-level nonprofit organizations are mentioned as well. Although residents also coordinate their own urban forestry activities without a public or quasi-public organization, this discussion is limited to activities that involve a government or nonprofit organization. It does not intend to prescribe particular strategies for urban forest management—choices are context specific within and across regions (Escobedo & Nowak, 2009) and left to municipalities. But I do illustrate how theory and an understanding of the resource can inform cases in which particular tools might be effective.

Public provision

Public goods are often publicly provided (e.g. highways, national defense). In urban forestry, many municipalities manage public, and less commonly, private trees. Municipalities plant trees, conduct routine maintenance, remove hazardous trees, inventory trees (bottom-up) or tree canopy (top-down) (US Forest Service, n.d.) and coordinate urban forest activities. Many cities across the country have adopted tree planting initiatives (McPherson & Young 2010), including Los Angeles[4], New York City[5], and Denver[6] that have each pledged to plant one million trees and cities, nonprofit organizations and residents have planted hundreds of thousands of trees toward those goals. Cities like Baltimore and Washington DC have a 311

[4] www.cityplants.org
[5] http://www.milliontreesnyc.org
[6] www.milehighmillion.org

hotline for citizens to call to request planting or maintenance for public street trees (Locke & Grove 2014).

Some characteristics of public goods suggest public provision. For example, government provision is reasonable if a public good has large fixed or up-front costs but low marginal costs or if individuals have constrained capacity to provide the good (Davis & Whinston 1967). A healthy urban forest is not quite the same as other large infrastructure projects like roads or railways because it is comprised of many small acts over time (individual planting or natural regeneration projects) rather one (or several) large installation(s). However, effective management of the urban forest considers the entire urban forest ecosystem and coordinates activities across space, a task unfeasibly undertaken by individual residents planting and maintaining trees. Public involvement, then, in urban forest management, seems highly justified, particularly in planning and coordination.

Although public provision is common in urban forestry, it is insufficient. Planting and maintenance is often limited to public land even though achieving meaningful gains in urban canopy cover requires more trees on private land (Locke & Grove 2014). Public planting on private land without collaboration with property owners is unlikely a palatable and/or legal strategy. So while public provision might be effective on public land, its overall influence is limited.

Contracting Governments also contract with nonprofit and private organizations to provide public goods. This is frequent in urban forestry, where city governments contract with private tree maintenance companies for tree care and removal and with local urban greening nonprofit organizations, commonly to plant trees. However, often cities will restrict the use of public money to plant on private land, so contracting is similarly limited.

Consider two models cities, Statusquopolis and Treeville. Both Statusquopolis and Treeville are mid-sized metropolitan areas. In city neighborhoods, there are tree lawns and sidewalks and houses sit on small plots of land. As one moves downtown, less undeveloped space is in private land, and greenspace is provided more heavily from parks and along streets. Statusquopolis has

a mix of urban forest policies. Canopy cover is 25% and both below optimal on public and private land.

Suppose Treeville relies solely on public provision (planting, maintenance and removal by the city) for their urban forestry policy. Treeville would have many trees on public land like tree lawns and parks, but private trees would be underprovided. If public provision included coordination of urban forestry activities among homeowners, businesses, developers and the city, the urban forest might be more diverse than in Statsquopolis. Public provision alone will not achieve forest optimality.

Private Property and a Pricing Mechanism

> *"There is substantial evidence that many of the contemporary values associated with forest and woodland are public or quasi-public goods and are not readily amenable to any relatively straightforward redefinition of property rights. For example, there is general consensus that biodiversity and landscape are valued highly by the general public, even though they do not present easy opportunities for commercial exploitation."* (Slee, 2006, p. 5)

One oft cited strategy for addressing the tragedy of the commons is to create and protect private property rights (i.e. parcel the common pool resource) so that users can restrict access to their parcel of land. Property rights offer one effective strategy to the tragedy because owners have an incentive to preserve the resource when they can capture its benefits. In the case of urban trees, assigning property rights will not sufficiently entice private property owners to produce to social optimality because owners cannot internalize the positive externalities (see Lant et al. 2008 for a similar argument with regard to ecosystem services). Additionally, parceling urban forests, leaving tree management to property owners, neglects the interconnected of the urban forest ecosystem (see McKean 2000 for similar concerns regarding parceling rural forests).

Suppose Treeville relies solely on private property rights for their urban forestry policy, so that residents can undertake any urban forestry activities on their land they choose. Treeville would have few trees on public land like tree lawns and parks, but might have more private trees than

under public provision. Still, given that private trees have positive externalities, private trees would be underprovided. Property rights alone will not achieve forest optimality.

Suppose Treeville residents are responsible for urban forest activities along the streets in front of their homes. They might plant a few street trees in front of their homes to enjoy benefits and increase their housing value, but there will be fewer street trees than under the public provision scenario.

One related strategy is to change the rights regarding urban trees. According to Slee (Slee, 2006, p. 10), "the clarification of property rights is necessary to know whether the policymaker should be making the polluter pay (if the property right for the external effect resides with the State), or compensating the owner for delivering the environmental service (if the owner has the right to deliver or deny delivery of the service)." Although ownership of the land on which trees grow does not change, the rights to the benefits of the tree can shift. If city residents had the rights to the benefits of private trees, then owners would have to pay to make changes to the flow of benefits ("the polluter pays"; e.g. they pay a fine for tree removal). If the rights lie with the property owner, then the city could compensate the owner for improving or protecting the flow of benefits from the trees on her property (e.g. owners get a tax break per tree on their property, offer grants for tree planting on private property).

Regulation

Governments can regulate the behavior of urban residents to promote tree care. Municipalities regulate an array of tree management activities. According to Profous and Loeb, "in the United States, which pioneered 'urban forestry', regulations are so diverse that there is no single representative example" (1990, p. 185). Many cities have tree ordinances that regulate the planting and removal of trees. Zoning laws and special policy areas designate land use and regulate tree activities (Loeb). Like with public provision, regulation is constrained by private property rights. Profous and Loeb argue that variety in regulation comes from the especially strong respect for private property rights in the United States and strong debate over the extent to which the government can intervene in behavior on private property (Profous & Loeb 1990). Municipalities are constrained in the extent to which they can regulate the behavior of land

owners. Municipalities can also use financial incentives like taxes and subsidies to encourage beneficial behavior. For example, in Japan, land owners with large trees can enter into a ten-year agreement under which they are subsidized to manage the area for public benefits (Profous & Loeb, 1990).

Treeville's command-and-control options are rather limited. Suppose Treeville offered grants to organizations and residents to plant and maintain trees, but they restrict plantings to happen on public land because the trees are provided with public funds. The number of public trees will be higher than in Statusquoville, but there will be fewer private trees. Suppose Treeville also incentivized property owners to plant and care for trees by offering grants for planting and maintenance on private land. In a scenario where both public and private plantings are incentivized, Treeville would have more public and more private trees than in Statusquoville, and more private trees than in any of the other single-strategy scenarios.

Coproduction

One final strategy for providing public goods is coproduction— an arrangement and a process in which government and citizens share responsibility for delivering services (Marschall 2004). Brudney and England define coproduction to include voluntary citizen involvement or participation with traditional producers (city governments, street level bureaucrats) in the delivery of urban services (1983). Individuals and groups can participate in coproduction. Effective coproduction requires clear and meaningful opportunities for citizens to participate, clear information about the responsibilities of citizens, and "structures and procedures that facilitate the flow of information between citizens and government" (Marschall, 2004). Coproduction is common in urban environments. For example, adopt-a-park programs engage urban residents in providing park management—groups pick up litter, mow grass, etc. (Brudney & England, 1983). Recent tree planting initiatives have often included engagement of nonprofits and private citizens (McPherson & Young, 2010). Nonprofit organizations often play a major role in urban forest coproduction. For example, they contract with the city to plant and maintain trees and they often engage city residents in tree planting and care.

Coproduction offers one strategy that might help address some of the challenges to urban forestry raised in this paper. The first of those challenges is that urban trees are managed on many public and private parcels of land by many individuals, yet the urban forest is best managed as an interconnected resource. Second, and relatedly, increasing tree cover on private land (and integrating private trees into system-wide management) is necessary to increasing canopy cover (Elmendorf et al. 2003), but it is particularly difficult because of the government's limited influence on private property. Public provision and regulation are limited on private land because of strong private property rights. In coproduction, some central agency can manage the urban forest as an interconnected resource. They can consider nearby trees when selecting species or they can make recommendations to property owners. The government can incentivize private trees (through bearing some of the costs). And through its engagement with private land owners, it can integrate activities on private land into city-wide urban forest management.

Urban trees provide many benefits directly to those who live nearby, so they, even public trees, need not be costless for those individuals. Coproduction might offer a way in which residents bear some of the costs of tree management, but those costs are supplemented with public resources in order to reach socially optimal canopy cover.

Suppose Treeville undertook a strategy of coproduction with city residents. This might include grants to residents for planting on public and private property, coupled with assistance in planting and maintenance and with central coordination of urban forest activities. Not only would Treeville have more public and private trees, the urban forest would be better managed as an interconnected resource. However, if coproduction is left to public trees, it will achieve the limited results that other strategies offer.

5.0 Conclusion

This paper has argued that the urban forest is a multi-faceted good. Identifying a market failure in which the urban forest is underprovided, it identifies and evaluates strategies to improve urban forest structure and function. Given the ecological and institutional complexity of the

urban forest, one single tool will help achieve optimal levels of the urban forest. However, this paper has offered some insights into the conditions under which certain strategies might be more effective. Incentivizing planting on private land and undertaking coproduction that engages nonprofit organizations and urban residents offers two potential opportunities to increase urban forestry activities, particularly on private land.

6.0 Resources

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