HOW GREEN IS GREENING? ASSESSING THE ENVIRONMENTAL VALUE OF GREENING VACANT LOTS

Megan Heckert
Department of Geography and Planning
West Chester University
West Chester, PA 19383

ABSTRACT: *Trees are known to provide myriad environmental benefits in urban environments, and many cities are now developing tree planting programs aimed at harvesting these benefits. One challenge for tree planting programs is identifying planting locations. In blighted areas, vacant lots may be potential locations, though they may also have drawbacks, particularly long-term uncertainty about the fate of the lot. This pilot study modeled the expected environmental benefits of a program in Philadelphia that plants trees and greens vacant lots as well as estimating the impacts of the program were it implemented on all vacant residential land in the city. Over 11 years, trees planted through the program are modeled to have had positive impacts in terms of carbon sequestration, air pollution reduction, and stormwater management, with benefits increasing substantially as the trees age. When compared to CO2 emissions, pollution rates, and stormwater reduction needs, however, the figures are modest at best, even if the program were extended city-wide. These findings suggest that tree planting on vacant lots may only be environmentally effective if it can be done with an expectation of the lots remaining undeveloped for a considerable length of time.*

Keywords: tree planting; vacant lots; modeling; i-Tree

INTRODUCTION

It is well established in the urban forestry literature that trees can provide significant environmental benefits to cities that maintain them (Nowak, Wang, and Endreny 2007). These benefits are wide ranging and include carbon sequestration, air pollution mitigation, reduction in the urban heat island effect, reductions in energy use, stormwater management, and improved water quality (Mcpherson, Nowak, and Rowntree 1994; Nowak 2006).

These environmental improvements can also be translated into monetary benefits through not only savings in environmental mitigation costs by municipal governments, but also potential savings to households from reduced energy use and reduced health care expenses as a result of air pollution reductions (McPherson and Simpson 2003; Wolf 2004). The USDA Forest Service has conducted extensive research on how to model not only the specific environmental benefits but also the cost savings associated with them, and has published studies of the urban forests of major US cities. Through this research, the Forest Service has calculated annual values of the urban forests of Chicago, Washington DC, and Philadelphia to be $2.3 billion, $3.6 billion, and $1.8 billion, respectively (Nowak et al. 2006, 2010; Nowak, Hoehn III, et al. 2007). This research also makes clear that the benefits provided by trees increase significantly as trees age and grow (McPherson et al. 2007).

As cities are increasingly concerned about sustainability and the environment (Daniels 2008), the early 2000s saw the establishment of several high profile tree planting programs in major cities. These programs often directly cite the environmental benefits of trees as a reason for planting. New York City, as part of its PlaNYC sustainability plan, has pledged to plant one million trees by 2030 (The City of New York 2007). Philadelphia likewise included tree planting in its sustainability plan, planning for 300,000 new trees by 2015 (City of Philadelphia 2009), contributing to a larger initiative to plant one million in the 3-state, 13-county metropolitan region (Plant One Million 2014). Baltimore plans to double its tree canopy by 2067 (Baltimore Office of Sustainability 2009). Atlanta plans to increase canopy coverage to 40% (City of Atlanta 2010).

One requirement for all of these projects is finding appropriate locations to plant these trees. They often focus on a variety of locations, including both publicly and privately owned properties. Vacant lots are often suggested as ideal planting locations, especially in older industrial cities with an abundance of such properties. For example the Baltimore, MD Department of Recreation and Parks website suggests that vacant lots can be a good place for communities to plant trees while also providing a “tree calculator” to let residents estimate the benefits of any trees they plant (City of Baltimore 2013). Philadelphia’s sustainability plan, Greenworks Philadelphia, notes that to achieve the goal of increasing canopy cover to 30%, it will be “seeking new spaces in which to plant trees, such as vacant lots and school yards" (City of Philadelphia 2009, p.6). In all of these cases, the environmental benefits of tree planting are explicitly highlighted as a reason to plant on vacant lots.

While older industrial cities tend to have a particularly large supply of blighted vacant lots, they are not alone in promoting tree planting on vacant land. Even growing cities such as New York City are considering vacant lots as potential planting sites. MilliontreesNYC, a partnership between NYC Parks and New York Restoration Project (NYRP) growing out of PlaNYC, solicits city residents to suggest potential planting sites on its website. This solicitation includes the note that "NYRP and its partners need your help to identify viable institutional and private properties for tree planting - including schoolyards, public housing campuses, new developments, business districts, and *vacant lots*." (milliontreesNYC 2013, emphasis added).

Though cities seem eager to embrace vacant lots as ideal planting locations for trees with the explicit intent of improving the environment, the nature of vacant lots in these areas suggests there may be challenges. The fact that long-term plans to redevelop vacant land would typically lead to the removal of trees may be a significant detractor when it comes to actually realizing environmental benefits. This is particularly challenging given the relationship between tree size and environmental impact. Tensions between those who would plant on vacant lots and those who would develop them are a staple of the literature on community gardens (Smith and Kurtz 2003). There is little readily available information on these new tree planting programs to suggest whether the question of longevity of plantings on vacant lots is systematically being addressed.

Though vacant land greening programs are receiving considerable attention by cities and by researchers, existing studies of these programs have so far focused heavily on the economic and social benefits of greening (such as Branas et al. 2011; Heckert & Mennis 2012), with environmental benefits remaining largely assumed. Given that tree planting projects on vacant lots may be subject to the same development pressures as other greening programs, the question arises as to just how much planting on them can be expected to improve the environment. This study aims to explore that question in two ways. First, I model the environmental benefits accrued by the 3,383 trees planted as part of a of a vacant land greening program in Philadelphia over the course of a decade. Second, I extend the model to estimate the benefits that would be accrued over 10 years if the program were extended to cover all vacant residential land in the city of Philadelphia. Because it relies on modeling rather than direct field work, this should be seen as a pilot project to start thinking about the environmental benefits of planting on vacant land.

The Philadelphia LandCare (PLC) program was developed in the late 1990's by the Pennsylvania Horticultural Society (PHS). It was initially created in partnership with a community development corporation (CDC) that wanted to use greening to address blight. Together, the CDC and PHS developed a simple and replicable approach to vacant land management that involved removing debris, bringing in new topsoil and grading the property, then planting grass and trees and putting up a split rail fence. The community responded positively to the program and PHS expanded to work in other neighborhoods, refining the program to the point that it was ultimately adopted by the city government as part of the city's official approach to managing vacant land. By 2010, over 5,000 individual lots had been 'cleaned and greened', and 3,383 trees had been planted through the program. For more information on the program, see Jost (2010). While the PLC program was initially developed to address blight and had no explicit environmental agenda, its potential for improving the environment is noted in Greenworks Philadelphia, which mentions the program by description (City of Philadelphia 2009).

The PLC program is among the first and longest-running large-scale municipal vacant land greening programs in the country, and as such it provides a useful framework for thinking about the potential implications of planting trees on vacant land while considering the constraints of actual programming.

DATA AND METHODS

This analysis relies on PLC records provided by PHS. Since the program's inception, PHS has tracked the number of trees planted on each greened vacant lot. The number of trees planted has varied considerably from year to year based on number of lots greened. Because the PLC database did not track tree plantings by species, planting data was supplemented by species-level information on trees ordered for PLC planting starting in 2005.

The approach is to model tree growth and mortality based on PHS's initial planting records. Those models of growth and mortality are then used to create PLC tree inventories for each year from 2000 through 2010. The USDA Forest Service conducted close monitoring of trees in selected cities in the US (McPherson et al. 2006, 2007) and combined that experience with a variety of scientific studies on environmental impacts of trees to develop the i-Tree suite of software, which enables users to model a range of environmental benefits based on an inventory or sample of existing trees (USDA Forest Service n.d.). I relied on i-Tree Streets v. 5.0 to calculate energy reduction, air pollution removal, carbon sequestration, and stormwater runoff reduction resulting from PLC plantings.

Tree species composition

PLC trees planted starting in 2005 were tracked by PHS based on species. Prior to 2005, information was available only for number of trees planted. Because quantification of benefits requires information on tree types, post 2005 plantings were used as a model for depicting species types used in prior plantings. For using i-Tree, individual trees must be identified if not by species then by type such as broadleaf deciduous large. I used the 2005-2010 tree species data to determine the overall tree type distribution. All tree species fit into three types – broadleaf deciduous small, medium, and large (BDS, BDM, and BDL, respectively). Overall, 45.2% of trees planted between 2005 and 2010 were BDL, 31.4% BDM, and 23.4% BDS. I used these percentages to assign types to trees planted between 2000 and 2004, thus trees planted between 2000 and 2004 were modeled not by specific species but by assumed type. Each tree was then individually modeled for growth and mortality over the ensuing study years. These percentages were also used in the modeling of tree planting benefits if PLC were extended to all vacant land.

Modeling tree growth and mortality

While the ideal approach to modeling environmental benefits would involve a direct field survey of PLC trees to measure growth and mortality, this can be an extremely time-consuming process (USDA Forest Service n.d.) and was beyond the scope of this analysis. Instead, I relied on existing research on growth and mortality to estimate changes in the tree population both for the PLC program and for the city-wide simulation.

Tree size is measured in i-Tree as diameter at breast height (DBH), which is defined as tree diameter 4.5 feet off the ground. PHS did not keep exact records of tree sizes, but all trees were ordered for planting at a caliper size (diameter 1 foot above the ground) between 5.08 and 6.35 cm (2 and 2.5 inches). Though caliper size is not exactly the same as DBH, it is the best estimate available for PLC trees at planting. Each tree was thus assumed as planted with a DBH of 5.08 cm. Many factors influence tree growth rates including local weather patterns and shading as well as the age of the tree – tree growth is not linear but S-shaped, with low initial growth followed by higher rates of growth then low growth late in life (McPherson et al. 2006, 2007). The Forest Service has published growth rate estimates for street trees in Chicago, IL based on tree genera and size class (Nowak 1994). Figures from the Chicago study were used to estimate annual increases in DBH for all trees based on assumed initial sizes of 5.08 cm DBH.

Not every tree that is planted survives. Urban tree mortality rates can vary based on tree size and age and the land use type on which the tree is planted (McPherson et al. 2007; Nowak, Kuroda, and Crane 2004). A recent meta-analysis of 16 studies of street tree survival rates found that average mortality rates ranged from 3.5 to 5.1% per year while an accompanying field study of Philadelphia street trees found a 4.5% mortality rate (Roman and Scatena 2011). A US Forest Service survey of municipal arborists in the Northeast region found that street tree mortality rates were reported at 2.8% per year for the first five years and dropped to .57% per year thereafter (McPherson et al. 2007). A study of urban trees in Baltimore that included not only street trees but also trees on other private and public property found an overall mortality rate of 6.6% per year, with lower mortality on residential properties as compared to commercial and industrial land uses and higher mortality for smaller trees as compared to larger trees (Nowak et al. 2004).

In the absence of any information on actual PLC tree survival rates, I used the mortality figures from these three studies to model low, medium, and high tree mortality rates for the purposes of estimating PLC tree survival. The low mortality estimate used the Forest Service's northeast tree study rates of 2.8% mortality over five years and .57% mortality for later years (McPherson et al. 2007). The medium mortality scenario employed the 4.5% mortality rate of the Philadelphia study (Roman and Scatena 2011). The high mortality rate used the size-based mortality estimates of the Baltimore study, assigning annual mortality rates of 9% to trees smaller than 7.6 cm in diameter at breast height (DBH) and 6.4% mortality to trees between 7.7 cm and 15.2 cm in DBH (Nowak et al. 2004). For each year starting with its planting year, each tree was assigned a random number between 0 and 1 and was considered to have survived that year if the number was larger than the mortality rate estimate. For example, a newly planted tree in the low mortality scenario was counted as surviving to the following year if its randomly assigned number was greater than .028. Each tree is included in the inventory for the year in which it was planted and once a tree was modeled as having not survived a year it was dropped from all subsequent years of the benefits analysis. The vacant land planting used both low and high mortality estimates to represent a potential range of benefits, and the differences between the modeled results can be seen as indicating the model's sensitivity to these assumptions. These varying mortality models are offered to suggest a potential range of benefits that would be accrued given variations in mortality.

Modeling environmental benefits

Environmental benefits were calculated using the US Forest Service's i-Tree Streets software package, formerly known as STRATUM. Released to the public in 2006, i-Tree Streets combines user-input tree inventory data with a series of scientific models developed by the Forest Service to estimate a range of environmental benefits derived from street trees including reductions in energy use, air pollution mitigation, carbon sequestration, and stormwater runoff reductions (McPherson 2010; McPherson et al. 2006, 2007). While the Forest Service has released a suite of software with several different applications, I chose i-Tree Streets because it is able to produce benefit estimates based on tree species and size estimates without requiring more extensive information that would need to be collected in the field. Ultimately, three sets of benefit estimates were calculated for PLC trees – one for each mortality scenario. For each scenario, benefits were calculated for each year between 2000 and 2010, for a total of eleven years of benefits per scenario. For the city-wide model, high and low- mortality estimates were calculated for ten years from planting.

Extending the analysis to all vacant land

To model the potential impacts of extending PLC to all vacant residential land in Philadelphia, I obtained a GIS database of all Philadelphia parcels from the Philadelphia Water Department (PWD) and isolated only residential vacant land. The PLC program typically plants trees not to cover the entire lot but along the lot frontage, spaced at intervals of 20-30 feet. Trees are not planted on individual mid-block parcels. To estimate the number of trees that would be planted, I used GIS to calculate frontage for all vacant parcels. I then selected those parcels that had more than 20 feet of frontage after combining adjacent parcels and divided the frontage value 25 to mirror the typical planting pattern of the PLC program. Parcels smaller than 20 feet in width were assumed to be inappropriate for planting. This yielded an estimated planting of 60,165 trees on 38,160 vacant residential parcels.

RESULTS

Of the 3,383 trees planted as part of the PLC program, the low mortality model calculated 3,062 trees remained alive in 2010 while the high mortality model estimated a 2010 tree population of 2,404. Table 1 shows trees planted per year and modeled tree population per year with low, medium, and high mortality estimates.

Table 1. Trees Planted in PLC Lots and Population Estimates Based on Mortality Models

Year	Number of trees planted	Cumulative planting to date	Low-mortality population estimate	Medium-mortality population estimate	High-mortality population estimate
2000	83	83	83	83	83
2001	116	199	195	194	188
2002	68	267	260	259	238
2003	277	544	530	525	496
2004	400	944	921	908	853
2005	420	1,364	1,315	1,290	1,202
2006	509	1,873	1,790	1,738	1,590
2007	611	2,484	2,342	2,256	2,045
2008	601	3,085	2,887	2,757	2,471
2009	65	3,150	2,887	2,702	2,340
2010	233	3,383	3,062	2,813	2,404

Yearly reductions in household energy use started at a low of 1.1 GJ of electricity and 2.3 GJ of natural gas in 2000 to a high of 128.5 GJ of electricity and 215 GJ of natural gas in the 2010 low mortality scenario. Overall, the low mortality model estimates 480.6 GJ of electricity savings between 2000 and 2011 as a result of PLC trees, while the high mortality model estimates 370.4 GJ. Total natural gas savings were estimated at 860 GJ in the low mortality model and 674.6 GJ in the high mortality model.

Stormwater runoff reduction through interception over the 11-year period was estimated between 6,654.7 m^3 in the high mortality model and 8,534.1 m^3 in the low mortality model, with each year showing an increase in overall interception amounts.

Air pollution mitigation effects were stronger in pollution avoidance through energy reductions than deposition, but ranged from net pollutant removal (after accounting for the release of biogenic volatile organic compounds) of 563.6 kg over 11 years in the high mortality model to 727.7 kg in the low mortality model. The largest pollutant-specific reductions were in NO_2 avoidance while the lowest were in VOC avoidance and $S0_2$ deposition.

Reductions in carbon dioxide ranged from net reduction (reduction though sequestration and avoidance less emissions from decomposition and maintenance) of 191,107 kg over 11 years in the high mortality scenario to 250,280 kg in the low mortality scenario. Table 2 indicates cumulative environmental benefits of the PLC program for each indicator.

Table 2. Cumulative Benefits of PLC Trees After 10 Years

	Low-mortality scenario	High-mortality scenario
Total trees remaining after 10 years	3,062	2,404
Electricity savings (GJ)	480.6	370.4
Natural gas savings (GJ)	860.0	674.6
Rainwater interception (m^3)	8534.1	6654.7
O_3 deposition (kg)	116.3	90.9
NO_2 deposition (kg)	43.5	34.1
PM10 deposition (kg)	110.5	86.5
SO_2 deposition (kg)	20.5	16.0
$NO2_2$ avoided (kg)	138.5	107.4
PM_{10} avoided (kg)	25.7	20.0
VOC avoided (kg)	25.1	19.4
SO_2 avoided (kg)	277.1	214.1
BVOC emissions (kg)	-29.5	-24.7
Net air pollutant reductions (kg)	727.7	563.6
CO_2 sequestered in biomass (kg)	203,999	155,280
CO_2 avoided through energy reductions (kg)	51,126	39,495
CO_2 released through decomposition (kg)	-3,559	-2,638
CO_2 released through maintenance activities (kg)	-1,286	-1,030
Net CO_2 reduction (kg)	250,280	191,107

Of the 65,015 trees estimated to be planted if PLC were extended to all vacant residential land, 50,956 survived 10 years in the low mortality scenario while 30,198 were modeled as surviving 10 years in the high mortality scenario. Table 3 depicts modeled annual benefits after ten years for these trees.

DISCUSSION

These figures seem to indicate that PLC trees have conferred substantial environmental benefits over the first decade of the program. But just how significant are these numbers? To put them in perspective, I compared them to national statistics on consumption and emissions.

The US Energy Information Administration's Residential Energy Consumption Survey (RECS) indicates that in 2005 there were 15.1 million households in the Mid-Atlantic region of the US, which consumed 41 billion kWh (147.6 million GJ) of electricity and 239 billion cf (252 million GJ) of natural gas (U.S. Energy Information Administration n.d.). Household consumption rates were thus approximately 9.8 GJ of electricity and 16.7 GJ of natural gas. Thus the low estimate of cumulative electricity reduction due to PLC (from the high mortality model) of 370.4 GJ is equivalent to annual electricity use of 38 Mid-Atlantic households while the natural gas reduction of 674.6 GJ is equivalent to annual natural gas use of 40 households. Even the model for trees on all vacant land shows modest energy benefits, suggesting that after 10 years, trees planted on vacant land could mitigate the electricity use of 226-382 households and the natural gas use of 217-367 households, with the lower bound represented by the high-mortality estimates and the upper bound represented by the low-mortality estimates.

Table 3. Cumulative Benefits of City-Wide Vacant Lot Tree Planting after 10 Years

Total trees remaining after 10 years	Low-mortality scenario	High-mortality scenario
Electricity savings (GJ)	50,956	30,198
Natural gas savings (GJ)	3,741.5	2,214.6
Rainwater interception (m^3)	6,121.9	3,624.3
O_3 deposition (kg)	63,116.2	37,323.2
NO_2 deposition (kg)	824.7	488.1
PM10 deposition (kg)	309.4	183.2
SO_2 deposition (kg)	781.8	462.7
$NO2_2$ avoided (kg)	144.5	85.6
PM_{10} avoided (kg)	1,057.4	625.7
VOC avoided (kg)	199.2	117.9
SO_2 avoided (kg)	194.4	115.0
BVOC emissions (kg)	2,159.4	1,277.6
Net air pollutant reductions (kg)	-50.6	-30.0
CO_2 sequestered in biomass (kg)	5,620.3	3,325.7
CO_2 avoided through energy reductions (kg)	1,730,639.5	1,024,822.4
CO_2 released through decomposition (kg)	398,465.1	235,748.6
CO_2 released through maintenance activities (kg)	-34,706.0	-20,540.5
Net CO_2 reduction (kg)	-7,666.2	-4,543.2

It is important to note that the benefits of PLC trees were not accrued evenly over the course of 11 years, as benefits increased significantly each year. This was due to increases in both total number of trees through new plantings as well as benefits per tree due to tree growth. Indeed, more than 24% of the cumulative energy benefits of PLC trees were accrued during the 11th year of the high mortality model. To put this in perspective, the 11th year of the study in the high mortality model had 17% of the trees if each year's trees were counted separately.

Cumulative air pollution effects in the high mortality model include reductions in NO_2 of 141.4 kg and 106.5 kg of particulate matter. The EPA estimates that annual average nitrogen oxide emissions per passenger vehicle are 11.4 kg lbs and large particulate matter emissions are .06 kg (US EPA Office of Transportation and Air Quality 2005), indicating cumulative 11-year tree benefits for PLC equivalent to one year of emissions of nitrogen oxides from 12 cars and one year emissions of large particulate matter from 1,774 cars. The city-wide estimates after ten years suggest annual NO_2 benefits equivalent to 71-120 cars and particulate matter benefits equivalent to 9,676-16,351 cars. As with energy benefits, air pollution benefits increased each year, with the final year of the high mortality model accounting for more than 25% of all energy avoidance benefits and over 24% of all deposition benefits.

Perhaps the most significant environmental impact attributable to PLC trees is stormwater reduction through rainfall interception. The City of Philadelphia has recently committed itself to a green infrastructure approach to reducing stormwater runoff to prevent combined sewer overflows (City of Philadelphia 2009; The Philadelphia Water Department 2009), an approach that includes many interventions of which greening vacant land is only one. Overall, the Philadelphia Water Department (PWD) has a goal to reduce stormwater runoff by 7.96 billion gallons (30.1 million m^3) per year (Garrison and Hobbs 2011). In light of that figure, the interception of 6,654.7 m^3 by PLC trees over 11 years (in the high mortality model) does not seem like a significant amount. Again these numbers increase significantly with time, such that the estimated rainfall interception for 2010, the last year of the study, was over 1,600 m^3 gallons, nearly 25% of the 11-year cumulative estimate. Though this 2010 figure represents .02% of the overall desired reduction in stormwater runoff, that figure is likely to continue to increase as PLC trees grow and increase in canopy size. PWD estimates that annual rainfall on one acre in Philadelphia is roughly 1 million gallons (3,785 m^3) (The Philadelphia Water Department 2009), indicating that so far PLC trees have mitigated 1.75-2.25 years of rainfall on one acre of land. It should, of course, also be noted that PLC lots likely have additional stormwater reduction benefits beyond tree canopy interception, given the lessening of soil compaction associated with the treatment, which also increases stormwater infiltration into the soil (Yang and Myers 2007), and that similar benefits might be accrued by other programs through the planting process, depending on how much soil compaction is lessened.

The model of tree planting on all residential vacant land suggests much larger contributions to stormwater runoff reduction, with annual interception of 37,323.2 m^3 in the high mortality model and 63,116.2 m^3 in the low mortality scenario after 10 years, representing .1-.2% of PWD's stormwater reduction goal.

The high mortality model estimated PLC trees to have reduced atmospheric CO_2 by 191,107 kg or approximately 191 metric tons. The World Bank estimate of per capital CO_2 emissions for the US in 2000 was 19.5 metric tons (data.worldbank.org), suggesting that PLC trees have reduced CO_2 equivalent to the annual emissions of 9.8 2000 US citizens. Given EPA estimated emissions of 4,427 kg per passenger car per year (US EPA Office of Transportation and Air Quality 2005), PLC carbon sequestration is also equivalent to the annual emissions of 43.1 cars. The city-wide estimates suggest annual benefits after 10 years equivalent to CO_2 emissions of 63-107 people or 279-471 cars.

Perhaps the most significant finding from all of these models is the relative importance of older trees. It is well documented that larger trees tend to confer significantly greater environmental benefits than smaller trees (Nowak et al. 2010), and this is very much the case with both the PLC estimates and those for expanding the program to all vacant residential land. The benefits accrued in the last year of the PLC models all greatly increase the share of trees present in that year compared to others. These results highlight the significance of older trees in accruing environmental benefits, and suggest that the interim nature of the PLC program (and presumably many other programs that would plant on vacant lots) may in fact represent a significant weakness in considering its potential for long-term environmental benefits.

Overall, these numbers tend to indicate relatively small environmental improvements attributable to the PLC program with the potential for substantial increases as the trees mature and grow or as the program expands to include more lots and more trees. Even extending PLC to all residential vacant land would have only modest effects in the short term. Perhaps more than anything these results suggest that the environmental impacts of PLC are highly dependent on how long planted lots remain undeveloped.

Policy Implications

The policy implications of this study depend in part on the primary goals of tree planting programs that target vacant land. If the primary goal of the program is environmental, planting trees on vacant land is likely to help reach those goals only if the land is expected to remain vacant for a considerable length of time – certainly longer than the decade modeled here. This is not to say that vacant land may not prove to be a valuable resource for achieving environmental goals, just that tree planting in particular may not be the most effective means of achieving those goals on vacant land.

That being said, these findings should not be taken to indicate that tree planting programs should not be considered for vacant land. Especially in instances where a program's primary goals are vacant land management and blight reduction, the environmental benefits provided by the program can be seen as added bonuses in addition to other economic and social benefits that the newly managed greenspaces may provide. The PLC program has been shown to increase surrounding property values, reduce gun-related crime, improve some measures of public health, and reduce disparities in greenspace access (Branas et al. 2011; Heckert & Mennis 2012; Heckert 2013; Wachter 2004). Though the environmental benefits are small, the fact that they exist at all may simply be another in a list of reasons for cities to consider green management strategies for vacant land.

It is important also to consider tree planting programs relative to their alternatives, which presumably include not just unmanaged vacant lots but also other uses such as redeveloping lots into homes or permanent greenspaces. In the case of redevelopment into homes, assuming that trees and any other plantings would be removed to make way for the buildings, it is clear that environmental benefits would be diminished. The case of redevelopment into permanent greenspace offers the opposite alternative – the promise of continued growth and management of trees with increasing environmental benefits. Thus tree planting on vacant land can be seen as neither the least nor the most environmental option for vacant land, but one that nonetheless offers environmental benefits even when used as a purely interim management option, especially if the alternative is to do nothing.

Limitations and Future Directions

This analysis puts actual numbers to the environmental benefits provided by the PLC program as well as its hypothetical extension to cover all residential vacant land in Philadelphia. The findings highlight both the potential and the limitations of this program in terms of reaching the environmental goals of sustainability plans. The analysis is not without limitations, however. These figures are derived from a series of models each of which provides an uncertain estimate – of mortality, of growth, and of environmental benefits – it does not involve any direct measurements of either trees or benefits.

Important future directions for this research would be to perform field studies to measure that actual growth and mortality of PLC trees. Additionally, this study ignores other potential benefits of the PLC program which should be weighed alongside the tree-derived benefits when making any policy decisions about the program. In addition to potential economic and social benefits described briefly above, there may also be additional environmental benefits of greening programs not captured here as they do not rely on trees specifically. In particular, stormwater runoff may be decreased not just by trees but also by reduced soil compaction (Yang and Myers 2007). It is also unclear what impact, positive or negative, the program may have on biodiversity.

Overall, this analysis suggests that vacant land may be a valuable environmental resource if used to plant trees in blighted communities. It does, however, also suggest that programs to do so should also consider (or be considered by) development initiatives during planning stages, as there is minimal environmental benefit to planting young trees and greening lots that will quickly be developed. In particular, this study suggests that environmental benefits of PLC and similar programs would be maximized if new housing development were targeted to non-greened lots, those lots that have been more recently greened, and greened lots containing the fewest trees in an attempt to preserve the largest number of the largest trees.

ACKNOWLEDGEMENTS

This research was funded in part by a University Fellowship from Temple University and a Doctoral Dissertation Research Grant from the US Department of Housing and Urban Development.

REFERENCES

Baltimore Office of Sustainability. (2009). The Baltimore Sustainability Plan.

Branas, C. C., Cheney, R. A., Macdonald, J. M., Tam, V. W., Jackson, T. D., & Ten Have, T. R. 2011. A difference-in-differences analysis of health, safety, and greening vacant urban apace. American Journal of Epidemiology. 174(11): 1296–1306.

City of Atlanta. 2010. City of Atlanta Sustainability Plan.

City of Baltimore. 2013. Places to Plant Trees. Department of Recreation and Parks Website. http://bcrp.baltimorecity.gov/SpecialPrograms/TreeBaltimore/PlacestoPlantTrees.aspx. (Accessed August 29, 2013).

City of Philadelphia. 2009. Greenworks Philadelphia.

Daniels, T. 2008. Taking the initiative: Why cities are greening now. In Growing Greener Cities: Urban Sustainability in the Twenty-First Century, ed. E. L. Birch & S. M. Wachter, pp. 11–27. Philadelphia, PA: University of Pennsylvania Press.

Garrison, N., & Hobbs, K. 2011. Rooftops to Rivers II: Green strategies for controlling stormwater and combined sewer overflows. Report of the Natural Resources Defense Council.

Heckert, M. 2013. Access and equity in greenspace provision: A comparison of methods to assess the impacts of greening vacant land. Transactions in GIS. 16(6): 808–827.

Heckert, M., & Mennis, J. 2012. The economic impact of greening urban vacant land: a spatial difference-in-differences analysis. Environment and Planning A. 44(12): 3010–3027.

Jost, D. 2010. Thinking big... and small. Landscape Architecture. March: 1–8.

McPherson, E. G. 2010. Selecting Reference Cities for i-Tree Streets. Arboriculture & Urban Forestry. 36(5): 230–240.

Mcpherson, E. G., Nowak, D. J., & Rowntree, R. A. 1994. Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project. USDA Forest Service Northeastern Forest Experiment Station. General Technical Report NE-186.

McPherson, E. G., & Simpson, J. R. 2003. Potential energy savings in buildings by an urban tree planting programme in California. Urban Forestry & Urban Greening. 2(2): 73–86.

McPherson, E. G., Simpson, J. R., Peper, P. J., Gardner, S. L., Vargas, K. E., Maco, S. E., & Xiao, Q. 2006. Piedmont Community Tree Guide: Benefits, Costs, and Strategic Planting. USDA Forest Service General Technical Report PSW-GTR-200.

McPherson, E. G., Simpson, J. R., Peper, P. J., Gardner, S. L., Vargas, K. E., & Xiao, Q. 2007. Northeast Community Tree Guide: Benefits, Costs and Strategic Planting. USDA Forest Service General Technical Report PSW-GTR-202.

milliontreesNYC. 2013. Tell Us About a Tree Planting Opportunity. milliontreesnyc.org. http://milliontreesnyc.org/html/plant/planting_opportunity.shtml. (Accessed August 29, 2013).

Nowak, D. J. 1994. Atmospheric Carbon Dioxide Reduction by Chicago's Urban Forest. In Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project, ed, E. G. McPherson, D. J. Nowak, & R. A. Rowntree, pp. 83–94. USDA Forest Service General Technical Report NE-186.

Nowak, D. J. 2006. Institutionalizing urban forestry as a "biotechnology" to improve environmental quality. Urban Forestry & Urban Greening. 5(2): 93–100.

Nowak, D. J., Hoehn III, R. E., Crane, D. E., Stevens, J. C., & Fisher, C. L. 2010. Assessing Urban Forest Effects and Values Chicago's Urban Forest. report of the Northern Research Station, USDA Forest Service.

Nowak, D. J., Hoehn III, R. E., Crane, D. E., Stevens, J. C., & Walton, J. T. 2006. Assessing Urban Forest Effects and Values: Washington, D.C.'s Urban Forest. report of the Northern Research Station, USDA Forest Service.

Nowak, D. J., Hoehn III, R. E., Crane, D. E., Stevens, J. C., & Walton, J. T. 2007. Assessing Urban Forest Effects and Values: Philadelphia's Urban Forest. report of the Northern Research Station, USDA Forest Service.

Nowak, D. J., Kuroda, M., & Crane, D. E. 2004. Tree mortality rates and tree population projections in Baltimore, Maryland, USA. Urban Forestry & Urban Greening. 2(3): 139–147.

Nowak, D. J., Wang, J., & Endreny, T. 2007. Environmental and Economic Benefits of Preserving Forests within Urban Areas : Air and Water Quality. In The economic benefits of land conservation, ed, C. T. F. de Brun, pp. 28–47. The Trust for Public Land.

Plant One Million. 2014. About Plant One Million. www.plantonemillion.org. http://www.plantonemillion.org/index.php/about/. (Accessed January 14, 2014.)

Roman, L. A., & Scatena, F. N. 2011. Street tree survival rates: Meta-analysis of previous studies and application to a field survey in Philadelphia, PA, USA. Urban Forestry & Urban Greening. 10(4): 269–274.

Smith, C. M., & Kurtz, H. E. 2003. Community gardens and politics of scale in New York City. Geographical Review. 93(2): 193–212.

The City of New York. 2007. plaNYC: A Greener, Greater New York.

The Philadelphia Water Department. 2009. Green City Clean Waters.

U.S. Energy Information Administration. n.d. Residential Energy Consumption Survey (RECS). www.eia.gov/consumption/residential/data/2001. (Accessed April 04, 2012.)

US EPA Office of Transportation and Air Quality. 2005. Emission Facts: Average Annual Emissions and Fuel Consumption for Gasoline-Fueled Passenger Cars and Light Trucks. EPA420-F-05-022.

USDA Forest Service. n.d. i-Tree Streets User's Manual v. 5.0.

Wachter, S. M. 2004. The Determinants of Neighborhood Transformations in Philadelphia Identification and Analysis :The New Kensington Pilot Study. Report to the William Penn Foundation.

Wolf, K. L. 2004. Public value of nature: Economics of urban trees, parks and open space. In Design with Spirit: Proceedings of the 35th Annual Conference of the Environmental Design Research Association, ed, D. Miller & J. A. Wise. Edmond, OR: Environmental Design Research Association.

Yang, J., & Myers, M. 2007. Study of stormwater runoff reduction by greening vacant lots in north Philadelphia. poster presented at 2007 Pennsylvania Stormwater Management Symposium, Villanova University. http://www3.villanova.edu/vusp/Outreach/pasym07/papers/PST_yang.pdf. (Accessed April 04, 2012)