CITY FOREST CREDITS

White Paper

City Forests: Function, Scale,
And Value of Climate and other Benefits

Collin Cutrone McMichael, Mark McPherson, and Aaron Nordman

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Urban Forest Carbon Registry, City Forest Credits, a 501(c)(3) non-profit organization

999 Third Ave. #4600

Seattle, WA 98104

info@cityforestcredits.org

(206) 623-1823

1. Introduction

An "urban forest" or "city forest" is the population of trees or woody biomass existing within the boundaries of a metropolitan area, city, or town. In the United States, there are approximately 5.5 billion urban trees.[1]

Cities and towns make up about 3.6% of the conterminous 48 United States, but they contain 80% of the population.[1,2,3] That means nearly 262 million people in the United States live in cities or towns that depend on the ecosystem services provided by their city's trees.[4]

As the national population urbanizes, trees and forests in cities have acquired greater significance and focus.[1] City forests are now recognized as essential elements in urban "green infrastructure," which is an interconnected web of natural elements and spaces that provide services such as stormwater reduction, carbon storage, energy savings, public health benefits, and air quality improvements.[1,3,5,6] Urban forests deliver enormous utility-like benefits in cities and towns, in the larger regions around them, and in the global climate.[1,7,8]

City forests also provide important human and social benefits. The presence of trees and urban greenery where people live and work can positively effect birth weight and development in infants, reduce symptoms of ADHD and respiratory illnesses in children and teens, reduce crime and cardiovascular disease, reduce hypertension and falls in older adults, and increase mobility in seniors.[9] Furthermore, increasing the tree cover in disadvantaged communities can help to correct imbalances of social and environmental equity.[10]

City Forest Credits has developed over the last year an Impact Scorecard (https://www.cityforestcredits.org/impact-certification/impact-standards/) that endeavors, for the first time that we are aware of, to identify the attributes of equity, health, and environmental impacts of urban forest projects. The Impact Scorecard

assess project-scale impacts in those three categories, with the impacts mapped to the United Nations Sustainable Development Goals. The goal is to give projects the first tool to demonstrate science-based equity and health impacts of projects.

2. Services Provided by Urban Forests

The value of a metropolitan forest is determined by the net benefits of all benefits felt by society.[6] Some of this value is based on concrete numbers, like the amount of stored carbon or the cost of managing stormwater. For example, nearly half of every tree by mass is carbon that has been removed from the atmosphere.[11] Additional benefits are now receiving renewed scientific attention, including increased human well-being and improved wildlife habitat.[3]

A substantial body of peer-reviewed science has documented over the last thirty years many of the benefits of city trees. Between technical manuals published by the U.S. Forest Service and its Urban Tree Database (UTD), which catalogs urban tree growth projections across regions, we can now calculate both the amount of stored carbon currently present in urban trees and the amount of carbon sequestered annually by their growth.[12,13] The UTD is the culmination of 14 years of work, analyzing more than 14,000 trees across the United States. Prior growth models typically featured only a few species specific to a given city or region; however, the 2016 UTD features 171 distinct species across 16 U.S. climate zones. The trees studied also spanned a range of ages with data collected from a consistent set of measurements. Advances in statistical modeling have given the projected growth dimensions a level of accuracy never before seen. Moving beyond just calculating a tree's diameter or age to determine expected growth, the research incorporates 365 sets of tree growth equations to project growth. [12,13]

City forests in the United States provide $18.3 billion in benefits per year, and this number is expected to grow as urban areas continue to expand.[1] This value is the

total value of all air pollution removal, carbon storage, avoided emissions, and energy savings, delivered by the trees in cities and towns in the United States.

2.1 Carbon Storage

Urban trees in the conterminous United States store about 770 million tons of carbon valued at $14.3 billion.[7] Every year as trees grow, they add to this. They sequester 36.7 million tons of carbon annually on top of what is already present, or $4.8 billion worth of carbon every year.[1] City forests in some temperate cities in the world are seeing rates of carbon sequestration rivaling those in tropical rainforests.[11] City forests thus represent a significant carbon sink for the atmosphere.

2.2 Air Pollution Removal

Trees are also capable of removing pollutants such as ozone, nitrogen dioxide, sulfur dioxide, and particulate matter from the air through surface deposition or leaf uptake.[1] Urban trees are generally capable of removing more air pollution, over 700,000 tons annually, because they are in environments with heavier pollution loads.[14] The amount of pollutants removed from urban environments equates to $5.4 billion saved annually on health expenses and productivity losses.[1]

2.3 Energy Savings

Trees planted in cities can dramatically reduce annual expenditures on air conditioning and heating by buffering against extreme temperatures, cold winds, and extreme weather.[8,15,16] This effect of trees on their immediate environment translates to energy savings from cooling and heating of $5.4 billion each year.[1] Similarly, because energy needs are lowered, powerplant emissions see reductions as well. Building related savings equate to $779 million annually by reducing peak energy loads by 10%, and annual savings of $2.7 billion by avoiding the release of thousands of tons of pollutants and volatile organic compounds.[1,16]

2.4   Stormwater Management

Stormwater management is a significant cost for cities and towns. Both federal and local regulations require management of stormwater by cities, towns, and certain private property owners. Many cities maintain a joint system for waste water and stormwater, with the result that during heavy rains, stormwater flows over into the wastewater system, creating expense and risk for cities and utilities.

There are no national studies on the effects of urban trees on stormwater, however some inferences can be made by observing case studies for individual cities, or through advanced modelling techniques. For example, Dayton, Ohio saw a reduction of 7% in stormwater runoff due to its tree canopy.[17] In Tucson, AZ stormwater management savings were calculated at $0.18 per tree per year, and 16% of the annual water requirements for each tree were offset by water conservation at the power plant due to reduced energy consumption.[18,19] Moreover, research in urban forestry in the last twenty years has resulted in databases that allow calculation of rainfall interception by species and climate zone. See Appendix B to the City Forest Planting Protocol for a description of the science underlying the calculation of rainfall interception.

City trees reduce storm water by offering two reservoirs of stormwater storage. The canopy intercepts and holds rainfall, and the soil and root systems hold stormwater in a second reservoir.[20,21] In light rainfall events, canopies can stop rainfall altogether; In heavier rain events, canopies serve to slow the water and reduce erosion.[21]

2.5   Water Quality

While few studies have looked at the effects of trees on water quality, trees do reduce runoff, rainfall intensity, and impacts on stormwater management systems. All of these effects can ultimately lead to changes in water quality. Reduced runoff and rainfall intensity could reduce erosion and thereby turbidity in watersheds.[21]

Trees can increase the amount of infiltration of rain in the soil resulting in further reduced runoff, increased nutrient uptake by the trees, and decreased nutrient load in watersheds.[20]

2.6   Health Benefits

Urban forests have been strongly linked to health, with trees showing significant improvements in people's well-being.[22] Studies have shown that an exposure to nature has a wide range of positive health effects, and urban forests can offer annual savings in avoided health care costs of $11.7 billion.[9] Most of the effects of trees on health come from the tree's ability to improve air quality, ameliorate summer heatwaves, and provide areas of outdoor recreation that provides multiple health benefits.[22]

More specifically, infants can see healthier birthweights, higher immune function, and better family dynamics with more trees present in their environment, and children and teens can see ADHD reductions and overall increases in health and well-being.[9] Adults can experience less depression and stress along with improved heart health when surrounded by a green canopy.[9] Finally, those later in life have better mobility, better quality of life, reduced blood pressure, and fewer cognitive disorders when they have access to their urban forest.[9]

A 2017 White Paper published by The Nature Conservancy documents in detail, with references, the many human and public health benefits of trees and nearby nature in cities and towns.[22] We refer readers to that resource.

2.7   Social Benefits

The presence of tree cover can increase the lifelong incomes of high school graduates by $1.3 billion annually, and reduced crime from increased urban tree cover can provide $928 million in avoided costs.[9] This allows for increased social mobility and an increased sense of safety and happiness. Trees also make cities more

aesthetically pleasing and can contribute to the economic vitality and empowerment of residents to improve their communities.[3]

2.8   Equity

Since urban tree cover is inequitably distributed in most areas, with more trees in affluent, majority neighborhoods, increasing tree cover across a region would help increase social equity.[10] Increasing tree cover means planting or allowing regeneration where there currently are few trees, therefore the vast majority of these effects would be felt in historically disadvantaged communities with low canopy cover. Equity also consists in many other attributes, some of which are captured in the Impact Scorecard developed by City Forest Credits (https://www.cityforestcredits.org/impact-certification/impact-standards/).

2.9   Other Benefits

City forests provide many other benefits, some well-studied and more yet unexamined, beyond the few cited above. These additional benefits include but are not limited to climate adaptation, ecosystem resiliency, noise reduction, slope stabilization, and biodiversity increases. The services provided by urban trees are manifold, and urban life would be radically different today without fully functioning city forests.

3.   Problems Facing Urban Forests

Urban forests are not static entities that remain unchanged throughout time. Like all natural systems, they face a host of problems, pressures, and potentially life-altering changes to their environment. These issues can in turn affect their structure, longevity, and composition.[1,6,23] In order to manage urban forests appropriately, correctly identifying the challenges facing our city's trees is of paramount importance.[3]

3.1 Continued decline of urban and community tree cover

Urban areas are increasing in size, most quickly along the eastern seaboard of the U.S. But this increase in urban land area will occur throughout the U.S., with urban expansion happening the fastest around already urbanized centers.[1,2] This means that areas already hit hardest by urbanization will continue to see its effects into the future. Development will continue, and that almost always means fewer trees and more impervious cover.[23]

Urban areas see the highest amount of canopy loss out of any other areas in the conterminous United States.[21] Declines in urban and community tree cover have been ongoing for decades with all but six states seeing a loss of canopy and only three showing a net increase.[23,24] Overall the U.S. loses approximately 36 million trees in urban and community areas annually.[24]

Urban and community tree cover declined by 175,000 acres per year in a study over 2009-2014.[24] The total land area of city forest tree cover lost during the five years of the study equals the combined land area of New York City, Miami, Boston, Atlanta, San Francisco, Seattle, Portland, OR, and Boise, ID. The dollar loss of that tree cover amounts to over $100 million worth of associated air quality improvement, storm water reduction, energy savings, and avoided emissions.

3.2 Expansion of urban land area

Urban growth is projected to add close to 100 million acres of urban land to the United States by 2060, an area roughly equivalent to the size of Montana.[1, 24] This new urban area could become green, healthy, and equitable, or it could become primarily roads, roof-tops, and other impervious surfaces if the city forests are not adequately protected and funded. Planning and regulations for these future urban areas can work toward preserving trees and forested stands. But funding for these new urban forests will be critical.[1,3,24]

3.3   Pervasive lack of funding for city forests

In spite of the unmatched returns on investment in urban forestry projects, city trees remain dramatically underfunded. The tree loss itself shows that public funding, which is virtually the only source of funding for those forests, is falling short. In most cities, funding for human services, transportation, utilities, public safety, homelessness, and refugee communities takes precedence over forests.[22]

Moreover, city budgets account for their trees as expenses. Trees require maintenance and create liability for cities. And because the natural capital of city forests is not recorded as an asset on a city's balance sheets, the only accounting category for trees in city budgets is as an expense.

 Most urban constituencies like their city trees. But there is widespread lack of knowledge, unclear jurisdictions, or lack of resources for city forests.[3,22,25] Generally, there is not enough funding to maintain a city's trees, much less preserve canopy cover.[3,22] Most municipal tree budgets address liability and maintenance expenses of hazardous trees through removals instead of expanding canopy through plantings.[22] And many "million tree" campaigns announced with the best of intentions remain aspirational due to lack of funding. The average budget allotted for and spent by municipalities throughout the United States investing in their own tree stock has decreased by 25% since the 1980s.[22]

The lack of readily available public funding for urban forests has led forestry professionals to seek private and alternative funding sources.[22,25] While cities do not account for trees as an asset but instead as an expense, corporations and private citizens see trees as possible routes to expand corporate social responsibility or individual environmental stewardship.[22]

4. Funding Urban Forests for the Future

One potential route of funding for urban forestry that has previously been unavailable is carbon development. Urban forests are able to sequester significant amounts of carbon, rivalling even the most productive natural systems.[11] In addition, the co-benefits of air quality improvements, stormwater mitigation, reduced heating and cooling costs, reduced power consumption, and human health are all delivered directly to metropolitan areas, where almost 80% of the population lives and works.[3]

The scientists advising City Forest Credits quantified some of these co-benefits to produce a unique bundled City Forest Carbon+ Credit. Each City Forest Carbon+ Credit includes one metric ton of CO_2 along with quantified rainfall interception, air quality improvements, avoided CO_2 emissions, and energy savings. Rainfall interception is expressed in resource units of cubic meters per year of avoided runoff. Air quality improvements are measured by the tons of pollutant removed per year for ozone, nitric oxide, and particulate matter. Avoided emissions are similarly measured by the tons of CO_2 kept out of the atmosphere, and energy savings are expressed in kWh per year and kBTU per year.

5. Potential for City Forest Carbon Storage and Co-Benefits

Many people experienced in carbon credit development, particularly from forestry projects, have regarded urban forests as lacking sufficient carbon storage potential to be worth developing. But the potential carbon storage and co-benefits of city forest projects may surprise many people not well-versed in urban forestry.[11]

CO_2 and Quantified Co-Benefits from City Forest Planting

For example, it may be quite realistic to plant 250 trees in 20 neighborhoods of 50 larger cities. Projected CO_2 storage after 25 years of those 250,000 trees is just under 500,000 tons, after mortality and a 5% buffer pool deduction. In the table

immediately below, the low dollar value is based on $20 per ton, the high value at $40 per ton.

Table 9. Summary of CO_2 stored after 25 years (includes tree losses, buffer pool deduction)			
Tree-Type	Total CO_2 (t) at 25 years	Low $ value	High $ value
Brdlf Decid	494514.2	$9,890,283.56	$19,780,567.12
Brdlf Evgrn	0.0	$0.00	$0.00
Conif Evgrn	0.0	$0.00	$0.00
Total	494514.2	$9,890,283.56	$19,780,567.12
	CO_2 (t)	Total $	Total $
Grand Total CO_2 (t) at 25 years:	494514.2	$9,890,283.56	$19,780,567.12
High Est. with Error:	568691.3	$11,373,826.10	$22,747,652.19
Low Est. with Error:	420337.1	$8,406,741.03	$8,406,741.03
± 15% error = ± 10% formulaic ± 3% sampling ± 2% measurement			

But even more surprising to many might be the quantified co-benefit values. The estimated co-benefits shown below in Table 10 are accrued annually after 25 years of growth. The rainfall interception per year of 1.2 billion liters leads to $8.8 million per year in avoided costs to manage that volume of stormwater. If these trees live to Year 51, the total dollar value of these benefits totals $443,083,850 in avoided costs.

Table 10. Co-Benefits (avoided costs) <u>per year</u> after 25 years (live trees, includes tree losses)				
Ecosystem Services	**Resource Units Totals**	**Res Unit/site**	**Total $**	**$/site**
Rainfall Interception (m3/yr)	1,233,568.20	4.93	$8,831,193.58	$35.325
CO2 Avoided (t, $20/t/yr)	28,845.89	0.12	$576,917.88	$2.308
Air Quality (t/yr)				
O3	16.6094	0.0001	$55,475.52	$0.222
NOx	2.6989	0.0000	$9,014.39	$0.036
PM10	8.6886	0.0000	$24,675.68	$0.099
Net VOCs	10.5448	0.0000	$87,177.31	$0.349
Air Quality Total	38.5418	0.0002	$176,342.90	$0.71
Energy (kWh/yr & kBtu/yr)				
Cooling - Elec.	37,913,068.78	151.65	$2,877,601.92	$11.51
Heating - Nat. Gas	540,466,627.53	2,161.87	$5,261,297.77	$21.05
Energy Total ($/yr)			$8,138,899.69	$32.56
Grand Total ($/yr)			$17,723,354.06	$70.89

CO$_2$ and Quantified Co-Benefits from City Forest Preservation

In addition, it may be realistic to preserve 50 acres of existing urban forest in those 50 large cities. CO$_2$ storage for those 2,500 acres may be very roughly estimated using GTR tables at approximately 150 tons per acre or 375,000 tons total.

As shown in Table 2 below, the annual and cumulative quantified co-benefits are significant. Rainfall interception alone is 1.7 billion liters per year. Over a 40-year project duration, the estimated dollar value of these co-benefits amounts to $283,281,160.

Table 2. Co-Benefits per year with current tree canopy cover.				
Ecosystem Services	Resource Units Totals	Res Unit/Acre Tree Canopy	Total $	$/Acre Tree Canopy
Rain Interception (m3/yr)	1,734,150.7	693.7	$3,665,311.96	$ 1,466.12
CO2 Avoided (t, $20/t/yr)	5,949.6	2.4	$118,992.74	$ 47.60
Air Quality (t/yr)				
O3	67.1134	0.0268	$139,729.54	$ 55.89
NOx	30.9856	0.0124	$64,511.82	$ 25.80
PM10	39.3694	0.0157	$148,397.45	$ 59.36
Net VOCs	3.2372	0.0013	$3,391.95	$ 1.36
Air Quality Total	140.7057	0.0563	$356,030.77	$142.41
Energy (kWh/yr & kBtu/yr)				
Cooling - Elec.	4,354,833	1,742	$610,112.16	$ 244.04
Heating - Nat. Gas	166,704,774	66,682	$2,331,581.62	$ 932.63
Energy Total ($/yr)			$2,941,693.78	$1,176.68
Grand Total ($/yr)			$7,082,029.26	$2,832.81

These values are estimates only. They are based on assumptions regarding species planted in in the Midwest or preserved in the Northeast. These values also assume a low level of mortality, but they give a rough order of magnitude for potential benefits and avoided costs. Projects like these will also provide significant as-yet-not-quantified benefits, such as human health, social equity, bird, pollinator, and wildlife habitat, slope stability, flood control, noise and visual buffering, and much more.

And perhaps most importantly, these benefits are delivered directly to where the people are. Given that the success of carbon markets depends upon entities purchasing carbon offsets and credits, it should not be forgotten that these city residents are valuable constituencies made up humans acting as voters, customers, donors, employees, volunteers, non-profit, civic and business participants and leaders, community activists, and so on.

Credit buyers can achieve unparalleled visibility through these city forest projects. Employees can volunteer, customers can see the benefits, and board members can literally drive to a park or neighborhood being transformed and watch people living and breathing in the midst of new project trees.

If the above examples seem remote or hypothetical, here are some examples of actual programs underway under the City Forest Credits Protocols now. Note that City Forest Credits has not promoted its work in any public way beyond connecting with its own network of urban forest organizations. Nor has City Forest Credits attempted to achieve scale at this time, preferring instead to work with a small number of early adopter programs to demonstrate success.

King County, WA

King County comprises the fast-growing cities of Seattle, Bellevue, Kirkland, Redmond, Shoreline, and others. King County is establishing an urban carbon program to preserve potentially hundreds of the last remaining stands of urban forest over as much as 2,000 acres. The carbon storage from these city forest properties is estimated at over 70,000 tons. The quantified co-benefits from this scale of preservation are estimated at over $2 million per year based on preserving 1,500 acres over the next ten years. These are preliminary estimates only. The final acreage of project area and quantified benefits will depend on city and county collaboration on funding and execution. But the scale and breadth of carbon storage, quantified ecosystem values, and other benefits, like public access to open space, are significant and valuable.

Austin, TX

In Austin, TX, a program has been developed for riparian plantings along up to 900 miles of degraded, mapped streams and rivers in Central Texas. Over 10,000 acres

have been mapped for potential reforestation. The City of Austin is currently purchasing offset credits on the carbon markets. Because these are purchased with taxpayer dollars, the City is very interested in locally sourced credits, so that taxpayer dollars and benefits stay local.

Des Moines, IA

In Des Moines, IA, a unique project funded by Microsoft includes CO_2 and quantified co-benefits from trees planted plus the social and economic benefits of a work force training program to give jobs and training in tree care to under-employed youth in Des Moines.

Other City Forest Project Types

Conservation Districts

Many counties in the U.S. have governmental entities known as conservation districts. These districts work to conserve resources in their jurisdictions, often doing significant riparian or stream and river re-forestation and habit restoration. These waterways are the circulation system for urban areas, and there are many large-scale opportunities to restore and re-plant deforested riparian areas. This will restore and protect water quality and quantity as well as fish and wildlife habitat, and it will deliver quantified environmental benefits along with recreation and other opportunities.

Urban Lumber in Certain States

A project under discussion in Clackamas County, OR is a unique urban lumber program in a state with a history of working forests. The County has mapped 1,500 acres of bare municipal land that could be planted with specialty hardwoods for

long-term management and harvest. With plantings on 1,500 acres of Potential Project Area, the estimated CO_2 sequestered amounts to 270,000 tons through Year 25. The total estimated value of quantified co-benefits through Year 51 are $76,951,775. The annual quantified co-benefits after Year 25 are shown below in Table 2.

Table 2. Co-Benefits per year after Year 25				
Ecosystem Services	**Resource Units Totals**	**Res Unit/Acre Tree Canopy**	**Total $**	**$/Acre Tree Canopy**
Rain Interception (m3/yr)	402,020.0	201.0	$2,951,687	$ 1,475.84
CO2 Avoided (t, $20/t/yr)	1,025.0	0.5	$20,500	$ 10.25
Air Quality (t/yr)				
O3	15.2560	0.0076	$6,505	$ 3.25
NOx	4.9793	0.0025	$2,123	$ 1.06
PM10	7.6092	0.0038	$5,764	$ 2.88
Net VOCs	-73.9175	-0.0370	-$11,735	$ (5.87)
Air Quality Total	-46.0731	-0.0230	$2,657	$1.33
Energy (kWh/yr & kBtu/yr)				
Cooling - Elec.	1,119,363	560	$57,311	$ 28.66
Heating - Nat. Gas	4,033,463	2,017	$45,916	$ 22.96
Energy Total ($/yr)			$103,227	$51.61
Grand Total ($/yr)			$3,078,071	$1,539.04

These are preliminary estimates only and are based on area-wide assumptions. Actual CO_2 storage will depend on quantification as part of a project. Also, while the target Project Area is approx. 1,500 acres that have been mapped, the final Project Area will depend on the success of city and county collaboration on funding and execution over the coming years.

For more information on these and more projects, the Project Registry of City Forest Credits lists some of these early adopter projects.

6. Conclusions

City forests deliver significant benefits to 80% of the population living in the cities and towns of the United States.[3] These benefits include, but are not limited to, carbon storage, stormwater reductions, energy savings, and air quality improvements. Other benefits that have not yet been quantified include human health benefits, social benefits, wildlife habitat improvements, slope stabilization, water quality improvements, and sound and visual buffering.[1,3,6,9]

Tree cover in cities is declining, so city residents see fewer and fewer of these benefits every year.[23] This trend is exacerbated as public funding falls short of tree cover loss.[3] Private sector funding is now critical to allow city forests to continue to deliver critical ecosystem and human benefits. The potential scale of city forest projects is significant, and urban areas are only slated to increase both in land area and population.[23]

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