TRAVIS COUNTY FLOODPLAIN REFORESTATION PROGRAM
Project Design Document

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PROJECT OVERVIEW

Basic Project Details

Project Name: Travis County Floodplain Reforestation Program
Project Planting Type: Riparian Planting
Project Location *(property name and city, town, or jurisdiction)***:** Travis County, Texas
Project Operator Name: TreeFolks
Project Operator Contact: Andreina Alexatos, Director of Reforestation, 512-443-5323, andreina@treefolks.org

Project Description

Include details of where the project will take place, how many trees will be planted, what type of planting, partners, overall project goals, and any other relevant information.

TreeFolks, Austin Office of Sustainability, Austin Watershed Protection Department and Travis County are launching the Travis County Floodplain Reforestation Program to restore healthy forest buffers of local rivers and streams in eastern Travis County. Carbon+ credits generated from this project will be sold to the City of Austin to help meet the city's 2020 carbon neutrality goal. Using funds allocated for carbon offsets to purchase local credits from these riparian plantings keeps the City of Austin's investments localized while addressing global climate change.

The pilot and program, both operated by TreeFolks, will reforest floodplain on public and private lands. TreeFolks will work with volunteers and youth service organizations to plant native saplings and provide the reforestation services to private owners free of charge. These services include, for those applicants who choose to participate and are selected, free trees, free planting services, and free consultations.

The tree planting projects will increase canopy cover and diversity in an ecosystem that needs help. The City of Austin Watershed Protection Department recently concluded that diverse wooded corridors along creeks and riparian zones here are rare.

The reforestation project also serves to engage local community members with the environment, complementing Austin's participation in the Biophilic Cities Network and the Children and Nature collaborative and aligning with citywide green infrastructure efforts. Reforesting Austin's local stream corridors will create lasting change, both within the city limits and across eastern Travis County floodplains.

The project will encompass 85.92 acres total, of which 45.54 are privately owned and the rest owned by the City of Austin or Travis County. We will be planting 47,279 saplings at 8' x 10' spacing, in order to provide canopy style coverage in these riparian zones.

LOCATION AND OWNERSHIP OF PROJECT AREA (Section 1.3, 2)

Location Eligibility

Project Areas must be located in parcels within or along the boundary of at least one of the following criteria. Describe how the Project Area(s) meet the location criteria.

- *A) The Urban Area boundary ("Urban Area"), defined by the most recent publication of the United States Census Bureau*
- *B) The boundary of any incorporated city or town created under the law of its state;*
- *C) The boundary of any unincorporated city, town, or unincorporated urban area created or designated under the law of its state;*
- *D) The boundary of land owned, designated, and used by a municipal or quasi-municipal entity such as a utility for source water or water shed protection;*
- *E) A transportation, power transmission, or utility right of way, provided the right of way begins, ends, or passes through some portion of A through D above.*

Ownership Eligibility

Project Operator must demonstrate ownership of property and eligibility to receive potential credits by meeting at least one of the following:

- *A) Own the land, the trees, and potential credits upon which the Project trees are located; or*
- *B) Own an easement or equivalent property interest for a public right of way within which Project trees are located, own the Project trees and credits within that easement, and accept ownership of those Project trees by assuming responsibility for maintenance and liability for them; or*
- *C) Have a written and signed agreement from the landowner granting ownership to the Project Operator of any credits for carbon storage or other benefits delivered by Project trees on that landowner's land. If Project trees are on private property, this agreement must be recorded in the property records of the county in which the land containing Project trees is located.*

Project Area Location

Describe where the Project Area is located and how it meets the location criteria.

The Project Area, including all plantings, are located in the Eastern portion of Travis County, Texas along degraded riparian corridors. The Travis County Floodplain Reforestation Program meets the following location criteria:

- *A) The Urban Area boundary ("Urban Area"), defined by the most recent publication of the United States Census Bureau*
- *B) The boundary of land owned, designated, and used by a municipal or quasi-municipal entity such as a utility for source water or water shed protection*

All plantings are within an urban boundary as defined by the 2010 Census and/or within or adjacent to Austin's Watershed Protection jurisdiction.

The urban areas included in this PDD are: Elgin,TX (26659); Austin, TX (04384); Manor, TX (54050); Del Valle, TX or Elroy, TX (27290).

Please see attachment: TCFRP Parcel Map; Jurisdiction_Map; TCFRP Pilot Project Area; TCFRP Planting Parcels; and individual property maps located in the “Property Maps” folder

Project Area Ownership and Right to Receive Credits

Describe the property ownership and include relevant documentation including title/filename as an attachment (Declaration of Land Ownership or Agreement from Owner to Transfer Credits.)

Private Land – A and C –There were two separate scenarios for including landowners in this program:

1. The landowner agrees to allow TreeFolks to transfer credits and signs an Agreement and Declaration of Covenants.
2. The landowner agrees to allow TreeFolks to transfer credits and signs an Agreement to Transfer Potential Credits.

Please see attachments: Agreement and Declaration of Covenants – Updated and Agreement to Transfer Potential Credits - Private

City and County Land – B – City of Austin and Travis County planted areas are on public parkland and have assumed a no-mow policy in the area. City or County shall not cut, harvest, or damage trees in the Tree Project except in cases of emergency involving fire or flooding or to mitigate hazard if trees are identified as a hazard by a certified arborist.

Please see attachments: Agreement to Transfer Potential Credits – Public

All signed and notarized agreements are saved in the “Right to Receive Credits” folder and labeled by property owner name. The original templates are also saved in the same folder.

Maps

Provide a detailed map of the Project Area. Also provide a map that shows the Project Area within the context of relevant urban/town boundaries. Include title/filename of relevant attachments.

1) Map of Project Area

TCFRP Pilot Project Area.JPEG
Jurisdiction_Map.PDF

2) Regional-scale map of Project Area

TCFRP Planting Parcels.JPEG
TCFRP Parcel Map.PDF
TCFRP Pilot Project Area.PDF
Note: Individual property maps are located in the “Property Maps” folder by owner name.

Additional Notes

PLANTING DESIGN

Describe planting design. Will the trees be planted as scattered single trees, clustered groups like parks plantings, or as riparian plantings (closely spaced with high expected mortality)?

Planting occurs during the winter months (Nov-Feb) through volunteer events or contracted labor. Planting is done on an 8'x 10' grid-like system with only 25% of the seedlings expected to reach maturity. The dense planting accounts for such a high mortality rate due to the fact that the seedlings are not cared for once planted. This method is called the Rapid Riparian Revegetation method (Guillozet et al., 2014) and it is intended to speed up the rate of natural recruitment by mimicking nature and adding native woody competition. Over time, the grasses and shrubs that initially take over the riparian area begin to lend way to other (more permanent) species that make up the future riparian forest. Sites will be chosen for reforestation if the planting area is within a floodplain, not already forested, and not be a highly incised bank (due to lack of connection to the water table).

Describe your data collection on Project Trees. For example, Project Operator can use the data collection sheet contained in the CFC quantification tool or your own method.

TreeFolks will use a range of tools to collect data on Project Trees, including geographic information systems (GIS) and the Theodolite app. GIS will be used to continually update Project maps and store data. The Theodolite app will be used to record photo points for all planting areas. The app includes a range of information on each photo, including coordinates and cardinal directions.

MONITORING AND REPORTING PLANS

Project Operator is required to submit an annual monitoring report. The report must contain any changes in eligibility status of the Project Operator and any significant tree loss. Confirm and describe your plans for annual monitoring of this project.

Monitoring of Project Trees will be done with geographic information systems (GIS), the Theodolite app, and canopy will be analyzed in year 4 and onward using i-Tree as well as any canopy information provided by USGS. GIS will be used to continually update Project maps and store data. The Theodolite app will be used to record photo points for all planting areas. The app includes a range of information on each photo, including coordinates and cardinal directions to ease the ongoing collection of survival data. TreeFolks will submit annual monitoring reports containing the required information using the template provided by City Forest Credits and in conformance with the attached CFC Planting Riparian Quantification and Monitoring Standards South Central document.

<u>Attachment – CFC Planting Riparian Quantification and Monitoring Standards South Central.pdf</u>

CARBON AND CO-BENEFITS QUANTIFICATION DOCUMENTATION (Section 12 and Appendix B)
Describe which quantification approach you anticipate using. When requesting credits after planting or in Years 4 or 6, attach one of the three documents below and provide the data you have collected for Project Trees.

1) *Single Tree Quantification Tool*
2) *Canopy Quantification Tool*
3) *Riparian Quantification with CO2 calculated per acre*

If your project is a riparian planting, provide the following:
- *General location of plantings on a map*
- *Most common 4 or 5 species and numbers of trees to be planted*
- *Approximate number of trees per acre*
- *Total acreage planted*

<u>Canopy/Riparian</u>
The approach for establishing carbon dioxide stored by tree canopy is outlined in a separate document prepared by Dr. Greg McPherson. Per the Riparian Quantification Approach, the CO_2 Index is 106.7 t CO_2 per acre of tree canopy. Therefore, this project is estimated to generate 9,167.66 credits. We request the issuance of 10% of the total (916 credits), less a 5% (45 credits) for the buffer pool upon successful third-party verification, for a total of 871 credits.

<u>Attachment – CFC Planting Riparian Quantification and Monitoring Standards South Central.pdf</u>

<u>Attachment – South_Preservation_CoBenefits 20191205.xls</u>

General Location of Plantings:
Please see maps

Most Common Species:
Pecan – Carya illinoinensis – 7,215
American Sycamore – Platanus occidentalis – 4,925
Bald Cypress – Taxodium distichum – 3,565
Honey Locust – Gleditsia tiacanthos – 3,060
Mexican Buckeye – Ungnadia speciose – 2,465

Total Trees Planted:
47,279

Total Acreage Planted:
85.92

Number of Trees per Acre
550/acre

Table 1. Tree Cover					
	Deciduous Tree Cover	**Coniferous Tree Cover**	**Total Tree Cover**	**Non-Tree**	**Total Project Area**
Percent (%)	90%	10%	100%	0%	100%
Area (sq miles)	0.121	0.013	0.134	0.000	0.13
Area (m2)	312,933	34,770	347,703	0	347,703
Area (acres)	77.328	8.59	85.92	0.00	85.92

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)	13,356.1	155.4	$34,933.95	$ 406.59
CO2 Avoided (t, $20/t/yr)	48.3	0.6	$966.77	$ 11.25
Air Quality (t/yr)				
O3	1.3742	0.0160	$4,082.85	$ 47.52
NOx	0.3484	0.0041	$1,035.10	$ 12.05
PM10	0.7755	0.0090	$875.89	$ 10.19
Net VOCs	-0.2091	-0.0024	-$593.66	$ (6.91)
Air Quality Total	2.2890	0.0266	$5,400.17	$62.85
Energy (kWh/yr & kBtu/yr)				
Cooling - Elec.	113,415	1,320	$8,608.18	$ 100.19
Heating - Nat. Gas	55,469	646	$576.34	$ 6.71
Energy Total ($/yr)			$9,184.52	$106.90
Grand Total ($/yr)			$50,485.42	$587.59

ADDITIONAL INFORMATION (OPTIONAL)

Include additional noteworthy aspects of the project. Examples include collaborative partnerships, community engagement, or project investors.

Partnerships. Strong partnerships with Travis County and City of Austin has meant regular and substantive support as we go about implementing the program. We have had the support of County and City administrations as we begin talks for program funding sustainability. The City of Austin's Watershed Protection Department has been regularly available for technical assistance in addition to providing a

$55,000 match. This initiative is funded in part by the Nature Conservancy in partnership with the Doris Duke Charitable Foundation**.**

Outreach. Initial outreach on behalf of the program was smooth. Data from Travis County Appraisal District was used to identify eligible parcels, with an initial batch of 119 parcels identified by our City of Austin partners as most desirable due to the lack of canopy cover along the riparian/floodplain area. From the Travis County 100-year floodplain database, 954 additional parcels were selected for their Farm and Ranch Improvement designation (as to avoid sending mailers to highly urban residential or commercial lots). Direct mailers were prepared for all 1,073 parcels and sent on 12/15/18.

Other outreach methods included active outreach to community groups including Wilbarger Creek Conservation Alliance, Pines and Prairies Land Trust, Austin-Bastrop River Corridor Partnership, Gilleland Creek Neighborhood Association, and the Colorado River Land Trust. “Campaign-style” highway signs were developed and deployed in areas near rural street intersections, and some were also given to program participants to advertise their participation and encourage neighbors to do the same. Finally, the program received press in the form of articles published in Texas Living Waters, Biophilic Cities, City Lab, and Pacific Standard.

PERFORMANCE STANDARD BASELINE METHODOLOGY (APPENDIX D)

There is a second additionality methodology set out in the WRI GHG Protocol guidelines – the Performance Standard methodology. This Performance Standard essentially allows the project developer, or in our case, the developers of the protocol, to create a performance standard baseline using the data from similar activities over geographic and temporal ranges.

The common perception, particularly in the United States, is that projects must meet a project specific test. Project-specific additionality is easy to grasp conceptually. The 2014 Climate Action Reserve urban forest protocol essentially uses project-specific requirements and methods.

However, the WRI GHG Protocol clearly states that either a project-specific test or a performance standard baseline is acceptable.[1] One key reason for this is that regional or national data can give a more accurate picture of existing activity than a narrow focus on one project or organization.

Narrowing the lens of additionality to one project or one tree-planting entity can give excellent data on that project or entity, which data can also be compared to other projects or entities (common practice). But plucking one project or entity out of its regional or national context ignores all comparable regional or national data. And that regional or national data may give a more accurate standard than data from one project or entity.

By analogy: one pixel on a screen may be dark. If all you look at is the dark pixel, you see darkness. But the rest of screen may consist of white pixels and be white. Similarly, one active tree-planting organization does not mean its trees are additional on a regional basis. If the region is losing trees, the baseline of activity may be negative regardless of what one active project or entity is doing.

Here is the methodology described in the WRI GHG Protocol to determine a Performance Standard baseline, together with the application of each factor to urban forestry:

[1] WRI GHG Protocol, Chapter 2.14 at 16 and Chapter 3.2 at 19.

Table 2.1 Performance Standard Factors

WRI Perf. Standard Factor	As Applied to Urban Forestry
Describe the project activity	Increase in urban trees
Identify the types of candidates	Cities and towns, quasi-governmental entities like utilities, watersheds, and educational institutions, and private property owners
Set the geographic scope (a national scope is explicitly approved as the starting point)	Could use national data for urban forestry, or regional data
Set the temporal scope (start with 5-7 years and justify longer or shorter)	Use 4-7 years for urban forestry
Identify a list of multiple baseline candidates	Many urban areas, which could be blended mathematically to produce a performance standard baseline

The Performance Standard methodology approves of the use of data from many different baseline candidates. In the case of urban forestry, those baseline candidates are other urban areas.[2]

As stated above, the project activity defined is obtaining an increase in urban trees. The best data to show the increase in urban trees via urban forest project activities is national or regional data on tree canopy in urban areas. National or regional data will give a more comprehensive picture of the relevant activity (increase in urban trees) than data from one city, in the same way that a satellite photo of a city shows a more accurate picture of tree canopy in a city than an aerial photo of one neighborhood. Tree canopy data measures the tree cover in urban areas, so it includes multiple baseline candidates such as city governments and private property owners. Tree canopy data, over time, would show the increase or decrease in tree cover.

Data on Tree Canopy Change over Time in Urban Areas

The CFC quantitative team determined that there were data on urban tree canopy cover with a temporal range of four to six years available from four geographic regions. The data are set forth below:

[2] See Nowak, et al. *"Tree and Impervious Cover Change in U.S. Cities,"* Urban Forestry and Urban Greening, 11 (2012), 21-30

Table 2.2 Changes in Urban Tree Canopy (UTC) by Region (from Nowak and Greenfield, 2012, see footnote 7)

City	Abs Change UTC (%)	Relative Change UTC (%)	Ann. Rate (ha UTC/yr)	Ann. Rate (m2 UTC/cap/yr)	Data Years
EAST					
Baltimore, MD	-1.9	-6.3	-100	-1.5	(2001–2005)
Boston, MA	-0.9	-3.2	-20	-0.3	(2003–2008)
New York, NY	-1.2	-5.5	-180	-0.2	(2004–2009)
Pittsburgh, PA	-0.3	-0.8	-10	-0.3	(2004–2008)
Syracuse, NY	1.0	4.0	10	0.7	(2003–2009)
Mean changes	-0.7	-2.4	-60.0	-0.3	
Std Error	0.5	1.9	35.4	0.3	
SOUTH					
Atlanta, GA	-1.8	-3.4	-150	-3.1	(2005–2009)
Houston, TX	-3.0	-9.8	−890	-4.3	(2004–2009)
Miami, FL	-1.7	-7.1	-30	-0.8	(2003–2009)
Nashville, TN	-1.2	-2.4	-300	-5.3	(2003–2008)
New Orleans, LA	-9.6	-29.2	−1120	-24.6	(2005-2009)
Mean changes	-3.5	-10.4	-160.0	-7.6	
Std Error	1.6	4.9	60.5	4.3	
MIDWEST					
Chicago, IL	-0.5	-2.7	-70	-0.2	(2005–2009)
Detroit, MI	-0.7	-3.0	-60	-0.7	(2005–2009)
Kansas City, MO	-1.2	-4.2	-160	-3.5	(2003–2009)
Minneapolis, MN	-1.1	-3.1	-30	-0.8	(2003–2008)
Mean changes	-0.9	-3.3	-80.0	-1.3	
Std Error	0.2	0.3	28.0	0.7	
WEST					
Albuquerque, NM	-2.7	-6.6	-420	-8.3	(2006–2009)
Denver, CO	-0.3	-3.1	-30	-0.5	(2005–2009)
Los Angeles, CA	-0.9	-4.2	-270	-0.7	(2005–2009)
Portland, OR	-0.6	-1.9	-50	-0.9	(2005–2009)
Spokane, WA	-0.6	-2.5	-20	-1.0	(2002–2007)
Tacoma, WA	-1.4	-5.8	-50	-2.6	(2001–2005)
Mean changes	-1.1	-4.0	-140.0	-2.3	
Std Error	0.4	0.8	67.8	1.2	

These data have been updated by Nowak and Greenfield.[3] The 2012 data show that urban tree canopy is experiencing negative growth in all four regions. The 2018 data document continued loss of urban tree cover. Table 3 of the 2018 article shows data for all states, with a national loss of urban and community tree cover of 175,000 acres per year during the study years of 2009-2014.

To put this loss in perspective, the total land area of urban and community tree cover loss during the study years totals 1,367 square miles – equal to the combined land area of New York City, Atlanta, Philadelphia, Miami, Boston, Cleveland, Pittsburgh, St. Louis, Portland, OR, San Francisco, Seattle, and Boise.

Even though there may be individual tree planting activities that increase the number of urban trees within small geographic locations, the performance of activities to increase tree cover shows a negative baseline. The Drafting Group did not use negative baselines for the Tree Planting Protocol, but determined to use baselines of zero.

Deployment of the Performance Standard baseline methodology for a City Forest Planting Protocol is supported by conclusions that make sense and are anchored in the real world:

- With the data showing that tree loss exceeds gains from planting, new plantings are justified as additional to that decreasing canopy baseline. In fact, the negative baseline would justify as additional any trees that are protected from removal.

- Because almost no urban trees are planted now with carbon as a decisive factor, urban tree planting done to sequester carbon is additional;

- Almost no urban trees are currently planted with a contractual commitment for monitoring. Maintenance of trees is universally an intention, one that is frequently reached when budgets are cut, as in the Covid-19 era. The 25-year commitment required by this Protocol is entirely additional to any practice in place in the U.S. and will result in substantial additional trees surviving to maturity;

- Because the urban forest is a public resource, and because public funding falls far short of maintaining tree cover and stocking, carbon revenues will result in additional trees planted or in maintenance that will result in additional trees surviving to maturity;

- Because virtually all new large-scale urban tree planting is conducted by governmental entities or non-profits, or by private property developers complying with governmental regulations (which would not be eligible for carbon credits under our protocol), and because any carbon revenues will defray only a portion of the costs of tree planting, there is little danger of unjust enrichment to developers of city forest carbon projects.

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[3] Nowak et al. 2018. "Declining Urban and Community Tree Cover in the United States," *Urban Forestry and Urban Greening,* 32, 32-55

Last, The WRI GHG Protocol recognizes explicitly that the principles underlying carbon protocols need to be adapted to different types of projects. The WRI Protocol further approves of balancing the stringency of requirements with the need to encourage participation in desirable carbon projects:

Setting the stringency of additionality rules involves a balancing act. Additionality criteria that are too lenient and grant recognition for "non-additional" GHG reductions will undermine the GHG program's effectiveness. On the other hand, making the criteria for additionality too stringent could unnecessarily limit the number of recognized GHG reductions, in some cases excluding project activities that are truly additional and highly desirable. In practice, no approach to additionality can completely avoid these kinds of errors. Generally, reducing one type of error will result in an increase of the other. Ultimately, there is no technically correct level of stringency for additionality rules. GHG programs may decide based on their policy objectives that it is better to avoid one type of error than the other.[4]

The policy considerations weigh heavily in favor of "highly desirable" planting projects to reverse tree loss for the public resource of city forests.

[4] WRI GHG Protocol, Chapter 3.1 at 19.

QUANTIFYING CARBON DIOXIDE STORAGE AND CO-BENEFITS FOR URBAN TREE PLANTING PROJECTS (Appendix B)

Introduction

Ecoservices provided by trees to human beneficiaries are classified according to their spatial scale as global and local (Costanza 2008) (citations in Part 1 are listed in References at page 16). Removal of carbon dioxide (CO_2) from the atmosphere by urban forests is global because the atmosphere is so well-mixed it does not matter where the trees are located. The effects of urban forests on building energy use is a local-scale service because it depends on the proximity of trees to buildings. To quantify these and other ecoservices City Forest Credits (CFC) has relied on peer-reviewed research that has combined measurements and modeling of urban tree biomass, and effects of trees on building energy use, rainfall interception, and air quality. CFC has used the most current science available on urban tree growth in its estimates of CO_2 storage (McPherson et al., 2016a). CFC's quantification tools provide estimates of co-benefits after 25 years in Resource Units (i.e., kWh of electricity saved) and dollars per year. Values for co-benefits are first-order approximations extracted from the i-Tree Streets (i-Tree Eco) datasets for each of the 16 U.S. reference cities/climate zones (https://www.itreetools.org/tools/i-tree-eco) (Maco and McPherson, 2003). Modeling approaches and error estimates associated with quantification of CO_2 storage and co-benefits have been documented in numerous publications (see References below) and are summarized here.

Carbon Dioxide Storage

There are three different methods for quantifying carbon dioxide (CO_2) storage in urban forest carbon projects:

- Single Tree Method - planted trees are scattered among many existing trees, as in street, yard, some parks, and school plantings, individual trees are tracked and randomly sampled
- Clustered Parks Planting Method - planted trees are relatively contiguous in park-like settings and change in canopy is tracked
- Canopy Method – trees are planted very close together, often but not required to be in riparian areas, significant mortality is expected, and change in canopy is tracked. The two main goals are to create a forest ecosystem and generate canopy
- Area Reforestation Method – large areas are planted to generate a forest ecosystem, for example converting from agriculture and in upland areas. This quantification method is under development

In all cases, the estimated amount of CO_2 stored 25-years after planting is calculated. The forecasted amount of CO_2 stored during this time is the value from which the Registry issues credits in the amounts of 10%, 40% and 30% at Years 1, 4, and 6 after planting, respectively. A 20% mortality deduction is applied before calculation of Year 1 Credits in the Single Tree and Clustered Parks Planting Methods. A 5% buffer pool deduction is applied in all three methods before calculation of any crediting, with these funds going into a program-wide pool to insure against catastrophic loss of trees. At the end of the project, in year 25, Operators will receive credits for all CO_2 stored, minus credits already issued.

In the Single Tree Method, the amount of CO_2 stored in project trees 25-years after planting is calculated as the product of tree numbers and the 25-year CO_2 index (kg/tree) for each tree-type (e.g., Broadleaf Deciduous Large = BDL). The Registry requires the user to apply a 20% tree mortality deduction before calculation of Year 1 Credits. Year 4 and Year 6 Credits depend on sampling and mortality data. A 5% buffer pool deduction is applied as well before calculation at any stage.

In the Clustered Parks Planting Method, the amount of CO_2 stored after 25-years by planted project trees is based on the anticipated amount of tree canopy area (TC). Because different tree-types store different amounts of CO_2 based on their size and wood density, TC is weighted based on species mix. The estimated amount of TC area occupied by each tree-type is the product of the total TC and each tree-type's percentage TC. This calculation distributes the TC area among tree-types based on the percentage of trees planted and each tree-type's crown projection area. Subsequent calculations reduce the amount of CO_2 estimated to be stored after 25 years based on the 20% anticipated mortality rate and the 5% buffer pool deduction.

In the Canopy Method, the forecasted amount of CO_2 stored at 25-years is the product of the amount of TC and the CO_2 Index (CI, t CO_2 per acre). This approach recognizes that forest dynamics for riparian projects are different than for park projects. In many cases, native species are planted close together and early competition results in high mortality and rapid canopy closure. Unlike urban park plantings, substantial amounts of carbon can be stored in the riparian understory vegetation and forest floor. To provide an accurate and complete accounting, we use the USDA Forest Service General Technical Report NE-343, with biometric data for 51 forest ecosystems derived from U.S. Forest Inventory and Assessment plots (Smith et al., 2006). The tables provide carbon stored per hectare for each of six carbon pools as a function of stand age. We use values for 25-year old stands that account for carbon in down dead wood and forest floor material, as well as the understory vegetation and soil. If local plot data are provided, values for live wood, dead standing and dead down wood are adjusted following guidance in GTR NE-343. More information on methods used to prepare the tables and make adjustments can be found in Smith et al., 2006. See Attachment A at the end of this Appendix for more information on the Canopy Method.

Source Materials for Single Tree Method and Clustered Parks Planting Methods

Estimates of stored (amount accumulated over many years) and sequestered CO_2 (i.e., net amount stored by tree growth over one year) are based on the U.S. Forest Service's recently published technical manual and the extensive Urban Tree Database (UTD), which catalogs urban trees with their projected growth tailored to specific geographic regions (McPherson et al. 2016a, b). The products are a culmination of 14 years of work, analyzing more than 14,000 trees across the United States. Whereas prior growth models typically featured only a few species specific to a given city or region, the newly released database 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.

Users select their climate zone from the 16 U.S. climate zones (Fig. 1). Calculations of CO_2 stored are for a representative species for each tree-type that was one of the predominant street tree species per reference city (Peper et al., 2001). The "Reference city" refers to the city selected for intensive study within each climate zone (McPherson, 2010). About 20 of the most abundant species were selected for sampling in each reference city. The sample was stratified into nine diameter at breast height (DBH) classes (0 to 7.6, 7.6 to 15.2, 15.2 to 30.5, 30.5 to 45.7, 45.7 to 61.0, 61.0 to 76.2, 76.2 to 91.4, 91.4 to 106.7, and >106.7 cm). Typically 10 to 15 trees per DBH class were randomly chosen. Data were collected for 16 to 74 trees in total from each species. Measurements included: species name, age, DBH [to the nearest 0.1 cm (0.39 in)], tree height [to the nearest 0.5 m (1.64 ft.)], crown height [to the nearest 0.5 m (1.64 ft.)], and crown diameter in two directions [parallel and perpendicular to nearest street to the nearest 0.5 m (1.64 ft.)]. Tree age was determined from local residents, the city's urban forester, street and home construction dates, historical planting records, and aerial and historical photos.

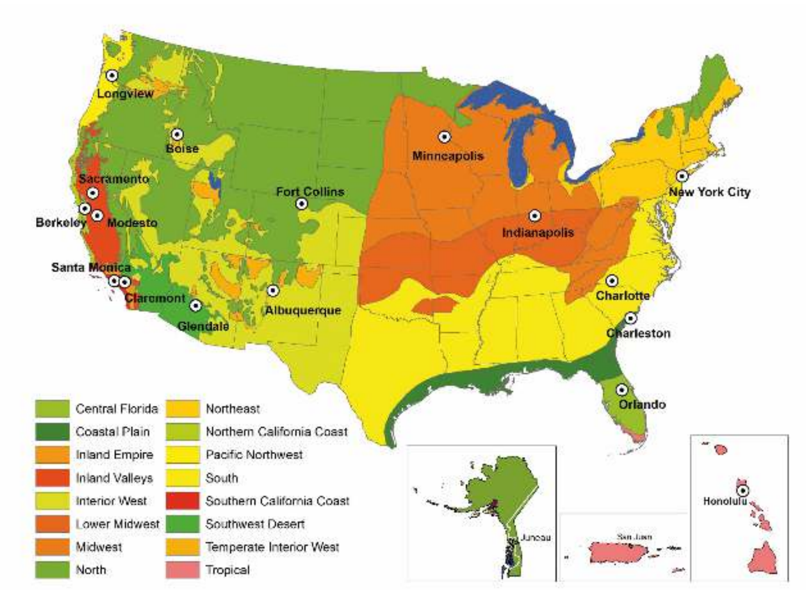

Fig. 1. Climate zones of the United States and Puerto Rico were aggregated from 45 Sunset climate zones into 16 zones. Each zone has a reference city where tree data were collected. Sacramento, California was added as a second reference city (with Modesto) to the Inland Valleys zone. Zones for Alaska, Puerto Rico and Hawaii are shown in the insets (map courtesy of Pacific Southwest Research Station).

<u>Species Assignment by Tree-Type</u>

Representative species for each tree-type in the South climate zone (reference city is Charlotte, NC) are shown in Table 1. They were chosen because extensive measurements were taken on them to generate growth equations, and their mature size and form was deemed typical of other trees in that tree-type. Representative species were not available for some tree-types because none were measured. In that case, a species of similar mature size and form from the same climate zone was selected, or one from another climate zone was selected. For example, no Broadleaf Evergreen Large (BEL) species was measured in the South reference city. Because of its large mature size, *Quercus nigra* was selected to represent the BEL tree-type, although it is deciduous for a short time. *Pinus contorta*, which was measured in the PNW climate zone, was selected for the CES tree-type, because no CES species was measured in the South.

Table 1. Nine tree-types and abbreviations. Representative species assigned to each tree-type in the South climate zone are listed. The biomass equations (species, urban general broadleaf [UGB], urban general conifer [UGC]) and dry weight density (kg/m^3) used to calculate biomass are listed for each tree-type.

Tree-Type	Tree-Type Abbreviation	Species Assigned	DW Density	Biomass Equations
Brdlf Decid Large (>50 ft)	BDL	*Quercus phellos*	600	*Quercus macrocarpa* [1.]
Brdlf Decid Med (30-50 ft)	BDM	*Pyrus calleryana*	600	UGB [2.]
Brdlf Decid Small (<30 ft)	BDS	*Cornus florida*	545	UGB [2.]
Brdlf Evgrn Large (>50 ft)	BEL	*Quercus nigra*	797	UGB [2.]
Brdlf Evgrn Med (30-50 ft)	BEM	*Magnolia grandiflora*	523	UGB [2.]
Brdlf Evgrn Small (<30 ft)	BES	*Ilex opaca*	580	UGB [2.]
Conif Evgrn Large (>50 ft)	CEL	*Pinus taeda*	389	UGC [2.]
Conif Evgrn Med (30-50 ft)	CEM	*Juniperus virginiana*	393	UGC [2.]
Conif Evgrn Small (<30 ft)	CES	*Pinus contorta*	397	UGC [2.]
[1.] from Lefsky, M., & McHale, M.,2008. [2] from Aguaron, E., & McPherson, E. G., 2012				

Calculating Biomass and Carbon Dioxide Stored

To estimate CO_2 stored, the biomass for each tree-type was calculated using urban-based allometric equations because open-growing city trees partition carbon differently than forest trees (McPherson et al., 2017a). Input variables included climate zone, species, and DBH. To project tree size at 25-years after planting, we used DBH obtained from UTD growth curves for each representative species.

Biomass equations were compiled for 26 open-grown urban trees species from literature sources (Aguaron and McPherson, 2012). General equations (Urban Gen Broadleaf and Urban Gen Conifer) were developed from the 26 urban-based equations that were species specific (McPherson et al., 2016a). These equations were used if the species of interest could not be matched taxonomically or through wood form to one of the urban species with a biomass equation. Hence, urban general equations were an alternative to applying species-specific equations because many species did not have an equation.

These allometric equations yielded aboveground wood volume. Species-specific dry weight (DW) density factors (Table 1) were used to convert green volume into dry weight (7a). The urban general equations required looking up a dry weight density factor (in Jenkins et al. 2004 first, but if not available then the Global Wood Density Database). The amount of belowground biomass in roots of urban trees is not well researched. This work assumed that root biomass was 28% of total tree biomass (Cairns et al., 1997; Husch et al., 2003; Wenger, 1984). Wood volume (dry weight) was converted to C by multiplying by the constant 0.50 (Leith, 1975), and C was converted to CO_2 by multiplying by 3.667.

Error Estimates and Limitations

The lack of biometric data from the field remains a serious limitation to our ability to calibrate biomass equations and assign error estimates for urban trees. Differences between modeled and actual tree growth adds uncertainty to CO_2 sequestration estimates. Species assignment errors result from matching species planted with the tree-type used for biomass and growth calculations. The magnitude of this error depends on the goodness of fit in terms of matching size and growth rate. In previous urban studies the prediction bias for estimates of CO_2 storage ranged from -9% to +15%, with inaccuracies as much as 51% RMSE (Timilsina et al., 2014). Hence, a conservative estimate of error of ± 20% can be applied to estimates of total CO_2 stored as an indicator of precision.

It should be noted that estimates of CO_2 stored using the Tree Canopy Approach have several limitations that may reduce their accuracy. They rely on allometric relationships for open-growing trees, so storage estimates may not be as accurate when trees are closely spaced. Also, they assume that the distribution of tree canopy cover among tree-types remains constant, when in fact mortality may afflict certain species more than others. For these reasons, periodic "truing-up" of estimates by field sampling is suggested.

Co-Benefit: Energy Savings

Trees and forests can offer energy savings in two important ways. In warmer climates or hotter months, trees can reduce air conditioning bills by keeping buildings cooler through reducing regional air temperatures and offering shade. In colder climates or cooler months, trees can confer savings on the fuel needed to heat buildings by reducing the amount of cold winds that can strip away heat.

Energy conservation by trees is important because building energy use is a major contributor to greenhouse gas emissions. Oil or gas furnaces and most forms of electricity generation produce CO_2 and other pollutants as by-products. Reducing the amount of energy consumed by buildings in urban areas is one of the most effective methods of combatting climate change. Energy consumption is also a costly burden on many low-income families, especially during mid-summer or mid-winter. Furthermore, electricity consumption during mid-summer can sometimes over-extend local power grids leading to rolling brownouts and other problems.

Energy savings are calculated through numerical models and simulations built from observational data on proximity of trees to buildings, tree shapes, tree sizes, building age classes, and meteorological data from McPherson et al. (2017) and McPherson and Simpson (2003). The main parameters affecting the overall amount of energy savings are crown shape, building proximity, azimuth, local climate, and season. Shading effects are based on the distribution of street trees with respect to buildings recorded from aerial photographs for each reference city (McPherson and Simpson, 2003). If a sampled tree was located within 18 m of a conditioned building, information on its distance and compass bearing relative to a building, building age class (which influences energy use) and types of heating and cooling equipment were collected and used as inputs to calculate effects of shade on annual heating and cooling energy effects. Because these distributions were unique to each city, energy values are considered first-order approximations.

In addition to localized shade effects, which were assumed to accrue only to trees within 18 m of a building, lowered air temperatures and windspeeds from increased neighborhood tree cover (referred to as climate effects) can produce a net decrease in demand for winter heating and summer cooling (reduced wind speeds by themselves may increase or decrease cooling demand, depending on the circumstances). Climate effects on energy use, air temperature, and wind speed, as a function of neighborhood canopy cover, were estimated from published values for each reference city. The percentages of canopy cover increase were calculated for 20-year-old large, medium, and small trees, based on their crown projection areas and effective lot size (actual lot size plus a portion of adjacent street and other rights-of-way) of 10,000 ft^2 (929 m^2), and one tree on average was assumed per lot.

Climate effects were estimated by simulating effects of wind and air-temperature reductions on building energy use.

In the case of urban Tree Preservation Projects, trees may not be close enough to buildings to provide shading effects, but they may influence neighborhood climate. Because these effects are highly site-specific, we conservatively apply an 80% reduction to the energy effects of trees for Preservation Projects.

Energy savings are calculated as a real-dollar amount. This is calculated by applying overall reductions in oil and gas usage or electricity usage to the regional cost of oil and gas or electricity for residential customers. Colder regions tend to see larger savings in heating and warmer regions tend to see larger savings in cooling.

Error Estimates and Limitations

Formulaic errors occur in modeling of energy effects. For example, relations between different levels of tree canopy cover and summertime air temperatures are not well-researched. Another source of error stems from differences between the airport climate data (i.e., Los Angeles International Airport) used to model energy effects and the actual climate of the study area (i.e., Los Angeles urban area). Because of the uncertainty associated with modeling effects of trees on building energy use, energy estimates may be accurate within ± 25 percent (Hildebrandt & Sarkovich, 1998).

Co-Benefit: CO_2 Avoided

Energy savings result in reduced emissions of CO_2 and criteria air pollutants (volatile organic hydrocarbons [VOCs], NO_2, SO_2, PM_{10}) from power plants and space-heating equipment. Cooling savings reduce emissions from power plants that produce electricity, the amount depending on the fuel mix. Electricity emissions reductions were based on the fuel mixes and emission factors for each utility in the 16 reference cities/climate zones across the U.S. The dollar values of electrical energy and natural gas were based on retail residential electricity and natural gas prices obtained from each utility. Utility-specific emission factors, fuel prices and other data are available in the Community Tree Guides for each region (https://www.fs.fed.us/psw/topics/urban_forestry/products/tree_guides.shtml). To convert the amount of CO_2 avoided to a dollar amount in the spreadsheet tools, City Forest Credits uses the price of \$20 per metric ton of CO_2.

Error Estimates and Limitations

Estimates of avoided CO_2 emissions have the same uncertainties that are associated with modeling effects of trees on building energy use. Also, utility-specific emission factors are changing as many utilities incorporate renewable fuels sources into their portfolios. Values reported in CFC tools may overestimate actual benefits in areas where emission factors have become lower.

Co-Benefit: Rainfall Interception

Forest canopies normally intercept 10-40% of rainfall before it hits the ground, thereby reducing stormwater runoff. The large amount of water that a tree crown can capture during a rainfall event makes tree planting a best management practice for urban stormwater control.

City Forest Credits uses a numerical interception model to calculate the amount of annual rainfall intercepted by trees, as well as throughfall and stem flow (Xiao et al., 2000). This model uses species-specific leaf surface areas and other parameters from the Urban Tree Database. For example, deciduous trees in climate zones with longer "in-leaf" seasons will tend to intercept more rainfall than similar species in colder areas shorter foliation periods. Model results were compared to observed patterns of rainfall interception and found to be accurate. This method quantifies only the amount of rainfall intercepted by the tree crown, and does not incorporate surface and subsurface effects on overland flow.

The rainfall interception benefit was priced by estimating costs of controlling stormwater runoff. Water quality and/or flood control costs were calculated per unit volume of runoff controlled and this price was multiplied by the amount of rainfall intercepted annually.

Error Estimates and Limitations

Estimates of rainfall interception are sensitive to uncertainties regarding rainfall patterns, tree leaf area and surface storage capacities. Rainfall amount, intensity and duration can vary considerably within a climate zone, a factor not considered by the model. Although tree leaf area estimates were derived from extensive measurements on over 14,000 street trees across the U.S. (McPherson et al., 2016a), actual leaf area may differ because of differences in tree health and management. Leaf surface storage capacity, the depth of water that foliage can capture, was recently found to vary threefold among 20 tree species (Xiao & McPherson, 2016). A shortcoming is that this model used the same value (1 mm) for all species. Given these limitations, interception estimates may have uncertainty as great as ± 20 percent.

Co-Benefit: Air Quality

The uptake of air pollutants by urban forests can lower concentrations and affect human health (Derkzen et al., 2015; Nowak et al., 2014). However, pollutant concentrations can be increased if the tree canopy restricts polluted air from mixing with the surrounding atmosphere (Vos et al., 2013). Urban forests are capable of improving air quality by lowering pollutant concentrations enough to significantly affect human health. Generally, trees are able to reduce ozone, nitric oxides, and particulate matter. Some trees can reduce net volatile organic compounds (VOCs), but others can increase them through natural processes. Regardless of the net VOC production, urban forests usually confer a net positive benefit to air quality. Urban forests reduce pollutants through dry deposition on surfaces and uptake of pollutants into leaf stomata.

A numerical model calculated hourly pollutant dry deposition per tree at the regional scale using deposition velocities, hourly meteorological data and pollutant concentrations from local monitoring stations (Scott et al., 1998). The monetary value of tree effects on air quality reflects the value that society places on clean air, as indicated by willingness to pay for pollutant reductions. The monetary value of air quality effects were derived from models that calculated the marginal damage control costs of different pollutants to meet air quality standards (Wang and Santini 1995). Higher costs were associated with higher pollutant concentrations and larger populations exposed to these contaminants.

Error Estimates and Limitations

Pollutant deposition estimates are sensitive to uncertainties associated with canopy resistance, resuspension rates and the spatial distribution of air pollutants and trees. For example, deposition to urban forests during warm periods may be underestimated if the stomata of well-watered trees remain open. In the model, hourly meteorological data from a single station for each climate zone may not be spatially representative of conditions in local atmospheric surface layers. Estimates of air pollutant uptake may be accurate within ± 25 percent.

Conclusions

Our estimates of carbon dioxide storage and co-benefits reflect an incomplete understanding of the processes by which ecoservices are generated and valued (Schulp et al., 2014). Our choice of co-benefits to quantify was limited to those for which numerical models were available. There are many important benefits produced by trees that are not quantified and monetized. These include effects of urban forests on local economies, wildlife, biodiversity and human health and well-being. For instance, effects of urban trees on increased property values have proven to be substantial (Anderson & Cordell, 1988). Previous analyses modeled these "other" benefits of trees by applying the contribution to residential sales prices of a large front yard tree (0.88%) (McPherson et al., 2005). We have not incorporated this benefit because property values are highly variable. It is likely that co-benefits reported here are conservative estimates of the actual ecoservices resulting from local tree planting projects.

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