# City Forest Credits
# Planting Project Application

Note: This is the second planting site under the Pierce Conservation District Reforestation Program – 2020 Planting Sites.

**1. Project Name**
Pierce Conservation District Reforestation Program – 2020 Project
Site #2: South Prairie Creek Preserve – Interior Floodplain Planting

**2. Project Type**
Planting project

**3. Project Location**
Unincorporated Pierce County, approximately one mile west of the town of South Prairie, WA.
Reference address for project: 13518 Pioneer Way East, Orting WA 98360.

**4. Project Operator**
*Organization:* Pierce Conservation District
*Address:* P.O. Box 1057
*City:* Puyallup
*State:* WA
*Zip:* 98371
*Contact(s):* Jayme Gordon
*Phone:* (253) 845-9770 ext. 102
*Email:* jaymeg@piercecd.org

**5. Project Description**
This project will restore native vegetation to an estimated 7.65 acres of riparian and floodplain habitat along South Prairie Creek, a tributary to the Carbon River in the Puyallup-White River watershed. Planting will take place in an area that lies between a newly constructed, half-mile long side channel and the right bank of South Prairie Creek.

This planting is part of a larger project to improve salmon habitat and restore floodplain processes. The project site had been utilized as pasture for many decades and is characterized by a mix of mostly non-native grasses and invasive weeds. Ultimately, a total of approximately 40 acres will be planted; prior to excavation and in-stream construction, 9.8 acres were planted Fall 2017-Spring 2020, and the remainder of the site will be planted over the course of two planting seasons. This application represents some of the planting scheduled to occur in the 2020-2021 season and the remainder of the site expected to be planted 2021-2022.

**6. Project Benefits**
This planting is part of a larger project to improve salmon habitat and restore floodplain processes in a high priority stretch of South Prairie Creek. Construction of a half-mile side channel and instream improvements to a half-mile of South Prairie Creek are intended to support adult to juvenile out-migrant survival and productivity for spawning, rearing, foraging, migrating, and overwintering life history stages for fall Chinook, Steelhead, Coho, Chum, Pink, and Cutthroat and Bull Trout.

However, the long-term success of this project – and the long-term achievement of self-sustaining ecosystem processes – depends on establishment of riparian and floodplain plant communities throughout the project site. This planting effort is the final piece of the project. Over time, the trees planted now will provide erosion control; floodplain and riparian habitat and ecosystem processes; shade to lower water temperatures; and contribute to instream habitat diversity, in addition to sequestering carbon.

**7. Total trees planted and planting-approach**
This is a riparian-type planting.

The planting plan submitted in this application is for a 7.65-acre area of former pasture fields. It is bordered to the north by a newly constructed (2020) half-mile long side channel and on the south by the mainstem of South Prairie Creek. Excluded from this application is a 2.65-acre area originally planted in the mid-2000s, a narrow linear strip along the face of the banks of the new side channel, and several small areas that have been reinforced with extra wood and rock (e.g. inlet and outlet of the side channel).

The interior floodplain is planted with a conifer/deciduous tree-shrub mix approximately 8’ on center. Bare root material is the primary plant stock suggested. However, live stakes were selected in order to minimize ground disturbance for one area along the right bank of South Prairie Creek where the bank is unstable, and alternate plant material (e.g. 1-gallon pots) may be used based on availability.

**Table 1: Plant List for Interior Floodplain**
**(only trees meeting CFC protocols are included)**
Plant Spacing = ~10’ on center

| Plant Name (common) | Plant Name (scientific) | # of Plants | Stock |
|---|---|---|---|
| Douglas fir | *Pseudotsuga menziesii* | 110 | bare root |
| Western red cedar | *Thuja plicata* | 800 | bare root |
| Sitka spruce | *Picea sitchensis* | 200 | bare root |
| Black cottonwood | *Populus balsamifera* | 600 | bare root |
| Black cottonwood | *Populus balsamifera* | 50 | 36" live stake |
| Oregon ash | *Fraxinus latifolia* | 150 | bare root |
| Big leaf maple | *Acer macrophyllum* | 485 | bare root |
| Red alder | *Alnus rubra* | 300 | bare root |
| Black hawthorn | *Crataegus douglasii* | 150 | bare root |
| Vine maple | *Acer circinatum* | 220 | bare root |
| | **Total:** | **3065** | |

See attached map for additional information about the planting plan.

**8. Does your project fall within an Urban Area mapped by the U.S. Census Bureau, or within the boundaries of a city or town? Choose one.** *Census Bureau mapping information link* https://www.census.gov/geographies/reference-maps/2010/geo/2010-census-urban-areas.html

___ Within an Urban Area   __X__ Within a city or town

**9. Additional Information**

This planting occurs on contiguous properties totaling 129 acres owned by both Pierce County and the Pierce Conservation District, and the project as a whole is done in partnership with Pierce County, the Puyallup Tribe of Indians, and the South Puget Sound Salmon Enhancement Group. This project is the culmination of a multi-year effort by these partners and others to identify high-priority opportunities to improve endemic salmonid populations, many of which are threatened and endangered.

November 19, 2020

Pierce Conservation District
308 W Stewart Ave
Puyallup, WA 98371
Attn: Ryan Mello, Executive Director and Jayme Gordon, Habitat Improvement & Environmental Education Director

Re: Approval of City Forest Credits application dated November 10, 2020

Dear Ryan and Jayme,

Thank you for submitting an application for the South Prairie Creek Preserve – Interior Floodplain Planting to be included in the 2020 Projects for the Pierce Conservation District Reforestation Program. I'm writing to let you know that City Forest Credits has approved your application dated November 10, 2020. Per our Project Implementation Agreement for 2020 Projects, this planting site will be included in the contract terms.

Thanks for your continued partnership.

Sincerely,

Liz Johnston

Liz Johnston
Director, City Forest Credits

info@cityforestcredits.org | 999 Third Avenue, Suite 4600, Seattle, WA 98104 | www.cityforestcredits.org

CITY FOREST CREDITS

# Pierce Conservation District Reforestation Carbon Program – 2020 Projects
# Site #2: South Prairie Creek Preserve – "Interior Floodplain Planting"
# Declaration of Land Ownership

I am the Executive Director of the Pierce Conservation District, and make this declaration regarding the ownership of land upon which the Pierce Conservation District is the Project Operator of a tree planting project referred to herein as the South Prairie Creek Preserve – Interior Floodplain Planting.

1. Land Ownership

The Pierce Conservation District is the owner in fee simple of the land identified in Section 2 and in Exhibit A.

2. Subject Lands

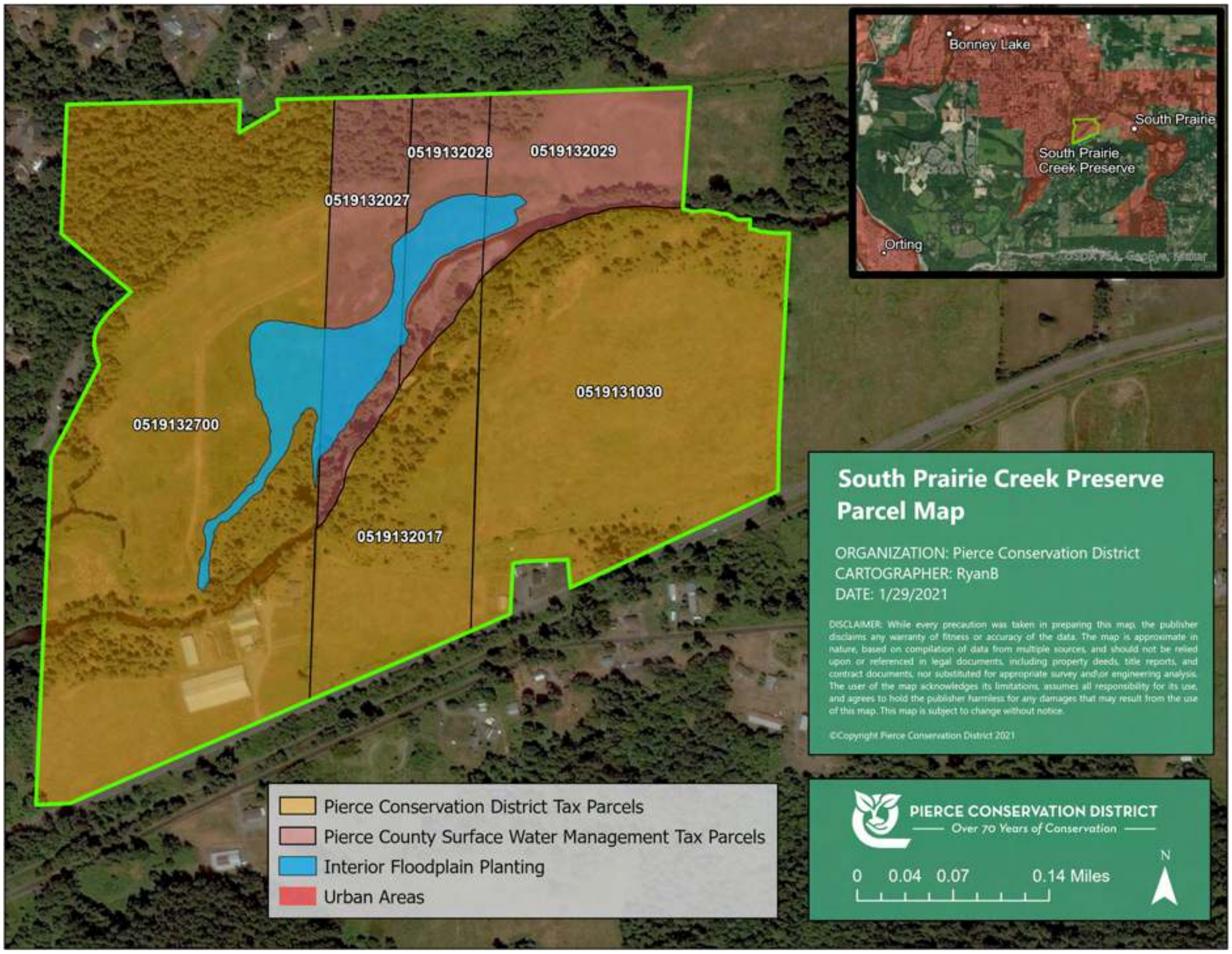
The Property upon which the South Prairie Creek Preserve – Interior Floodplain Planting Project is planting trees, and which is the subject of this Declaration, is specified in Exhibit A.

Signed this 10th day of February, 2021 in Puyallup, WA:

| | |
|---|---|
| **Name:** | Ryan Mello |
| **Title:** | Executive Director |
| **Address:** | P.O. Box 1057<br>Puyallup, WA 98371 |
| **Phone:** | (253) 845-9770 x107 |
| **Email:** | ryanm@piercecd.org |
| **Signature:** | Ryan N Mello |
| **Date:** | 02/10/2021 |

**Exhibit A**

Specification of Property (can be maps, legal description, and/or other reasonably specific delineations of the property upon which the project is taking place)




Description: The South Prairie Creek Preserve is comprised of six Pierce County tax parcels, three of which are owned by the Pierce Conservation District: 0519132700, 0519132017, and 0519131030. Of the three parcels owned by Pierce Conservation District, the Interior Floodplain Planting lies within parcel 0519132700 only.

Address: A reference address for the project site is 13518 Pioneer Way E., Orting, WA 98360.

# Pierce Conservation District Reforestation Carbon Program – 2020 Projects
# Site #2: South Prairie Creek Preserve – Interior Floodplain Planting
# Project Design Document

## Table of Contents

## PROJECT OVERVIEW

### Basic Project Details

**Project Name**: Pierce Conservation District Reforestation Carbon Program – 2020 Projects, Site #2: South Prairie Creek Preserve – Interior Floodplain Planting
**Project Number:** 007
**Project Type:** Planting
**Project Start Date:** November 19, 2020
**Project Location:** South Prairie, Pierce County, WA
**Project Operator Name:** Pierce Conservation District
**Project Operator Contact Information:** Jayme Gordon; jaymeg@piercecd.org; (253) 845-9770 ext. 102

### 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.*

This riparian planting project will restore native vegetation to an estimated 7.65 acres of floodplain habitat along South Prairie Creek, a tributary to the Carbon River in the Puyallup-White River watershed. Planting will take place in an area owned by Pierce Conservation District and Pierce County that lies between a newly constructed, half-mile long side channel and the right bank of South Prairie Creek.

This planting is part of a larger project to improve salmon habitat and restore floodplain processes. The project site had been utilized as pasture for many decades and is characterized by a mix of mostly non-native grasses and invasive weeds. Ultimately, a total of approximately 40 acres will be planted. Prior to excavation and in-stream construction, 9.8 acres were planted Fall 2017-Spring 2020, and the remainder of the site will be planted over the course of two planting seasons. This application represents the planting scheduled to occur in the 2020-2021 season. The remainder of the site expected to be planted 2021-2022 will be submitted in the 2021 application and documentation.

## 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 watershed 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.*

This project is eligible per the definition of Option A: The Urban Area boundary ("Urban Area"), defined by the most recent publication of the United States Census Bureau.

The project area is located between RM 4.0 and 4.5 on South Prairie Creek in east Pierce County, WA. It is located approximately one mile west of the town of South Prairie on property known as the "South Prairie Creek Preserve." Reference address is 13518 Pioneer Way East, Orting WA 98360.

**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.)*

This project is eligible under conditions A & C: The Pierce Conservation District (PCD) owns the land, trees, and credits on part of the project area. Pierce County (PC) owns the land on the other part of the project area. There is an agreement between PC and PCD for the site prep and planting of trees for the salmon recovery project. We have attached a *Declaration of Ownership* for PCD-owned land and *Agreement to Transfer Credits* between PCD and PC.

The property is comprised of six Pierce County tax parcels. Parcels 0519132700, 0519132017, and 0519131030 are owned by PCD; parcels 0519132027, 0519132028, and 0519132029 are owned by Pierce County Surface Water Management. Pierce County and PCD have a landowner agreement for the planting work associated with the salmon recovery project.

1 - PCD South Prairie Declaration of Ownership
2 - PCD and PC South Prairie Agreement to Transfer Credits

**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**

   *Title/filename of relevant attachment(s)*

   SPCP Interior Floodplain Map

2) **Regional-scale map of Project Area**

   *Title/filename of relevant attachment(s)*

   SPCP Vicinity Map

**PLANTING DESIGN**

*Describe planting design. Will the trees be planted as scattered single trees, clustered groups like parks plantings, or closely spaced such as riparian plantings?*

The trees are planted throughout the project site following the CFC riparian planting method. For the 7.65-acre project area, a planting density of 401 plants/acre was used as a general guideline; this equates to 3,065 trees. They are planted throughout the site on an average of 10' spacing. Nine species of trees and woody shrubs native to the Puget Sound lowlands were selected for this site. Microtopography and specific site features influenced species selection and planting design.

*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.*

Data collection on project trees will follow the planting Monitoring Manual developed by Pierce Conservation District Habitat Improvement staff. The monitoring manual describes the protocol used to establish monitoring plots and transects within the planting area; methodology for collecting line point intercept data; and noting qualitative observations about plant conditions. We will incorporate the Forest Ecosystem modification to the traditional Tree Canopy Approach for riparian tree planting projects as described in the "City Forest Credits Planting Protocol – Riparian Planting Quantification and Monitoring, Standards and Requirements in the Pacific Northwest" document into our monitoring protocol at this project site.

**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.*

As mentioned above, the Pierce Conservation District's Habitat Improvement team already utilizes a monitoring protocol. Revegetation monitoring is conducted annually via a series of randomized plots that aim to sample 2%-5% of the planting area and 10%-20% of the installed plants. Data collected via line point intercept, photo monitoring, and vegetation height/DBH allows us to assess plant survival, species diversity, and other changes in site characteristics we expect to see over time. Also monitored within each plot is general plant health and vigor (by species). Tree canopy monitoring, as described in the "City Forest Credits Planting Protocol – Riparian Planting Quantification and Monitoring, Standards and Requirements in the Pacific Northwest" document, will be added to our monitoring protocol for Years 3, 5, and 25. Aerial imagery obtained via drone or publicly available GIS imaging will be used to assess tree canopy coverage.

The District will submit a copy of its annual monitoring report for this site to CFC. In addition to data collected by the District, any other information required by CFC will be incorporated into the report as needed.

**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*

***Total Trees Planted:***

3,065

***Total Acreage Planted:***

7.65

***Number of Trees per Acre:***

401/acre

| Row Labels | Sum of No. Sites Planted |
|---|---|
| bigleaf maple | 485 |
| black cottonwood | 650 |
| black hawthorn | 150 |
| Douglas fir | 110 |
| Oregon ash | 150 |
| red alder | 300 |
| Sitka spruce | 200 |
| vine maple | 220 |
| western red cedar | 800 |
| **Grand Total** | **3065** |

**Table 3. Credits are based on 10%, 40%, and 30% at Years 1, 3, and 5 after planting, respectively, of the projected CO2 stored by live trees 25-years after planting. These values account for anticipated tree losses and the 5% buffer pool deduction.**

| | | | | | | 10% | 40% | 30% |
|---|---|---|---|---|---|---|---|---|
| | No. Sites Planted | No. Live Trees | Mortality Deduction (%) | 25-yr $CO_2$ stored (kg/tree) | Tot. 25-yr $CO_2$ stored w/ losses and 5% deduction (t) | 10% $CO_2$ (t) | 40% $CO_2$ (t) | 30% $CO_2$ (t) |
| BDL | 1285 | 1028 | 0.20 | 2,062.82 | 2014.6 | 201.46 | 805.82 | 604.37 |
| BDM | 300 | 240 | 0.20 | 1,277.75 | 291.3 | 29.13 | 116.53 | 87.40 |
| BDS | 370 | 296 | 0.20 | 604.21 | 169.9 | 16.99 | 67.96 | 50.97 |
| BEL | 0 | 0 | 0.20 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 |
| BEM | 0 | 0 | 0.20 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 |
| BES | 0 | 0 | 0.20 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 |
| CEL | 1110 | 888 | 0.20 | 1,520.44 | 1282.6 | 128.26 | 513.06 | 384.79 |
| CEM | 0 | 0 | 0.20 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 |
| CES | 0 | 0 | 0.20 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 |
| | 3065 | 2452 | | 5,465.2 | 3758.4 | 375.84 | 1503.37 | 1127.53 |

**Co-Benefits PER YEAR after 25 years (all live trees, includes tree losses)**

| Ecosystem Services | Resource Units Totals | Res Unit/site | Total $ | $/site |
|---|---|---|---|---|
| Rain Interception (m3/yr) | 15,616.68 | 5.10 | $114,647.41 | $37.405 |
| CO2 Avoided (t, $20/t/yr) | 150.04 | 0.05 | $3,000.84 | $0.979 |
| Air Quality (t/yr) | | | | |
| O3 | 0.4719 | 0.0002 | $977.87 | $0.319 |
| NOx | 0.1527 | 0.0000 | $316.34 | $0.103 |
| PM10 | 0.2602 | 0.0001 | $957.89 | $0.313 |
| Net VOCs | -1.3956 | -0.0005 | -$1,076.85 | -$0.351 |
| Air Quality Total | -0.5109 | -0.0002 | $1,175.25 | $0.38 |
| Energy (kWh/yr & kBtu/yr) | | | | |
| Cooling - Elec. | 163,853.41 | 53.46 | $8,389.29 | $2.74 |
| Heating - Nat. Gas | 512,906.98 | 167.34 | $5,838.77 | $1.90 |
| Energy Total ($/yr) | | | $14,228.06 | $4.64 |
| Grand Total ($/yr) | | | $133,051.56 | $43.41 |

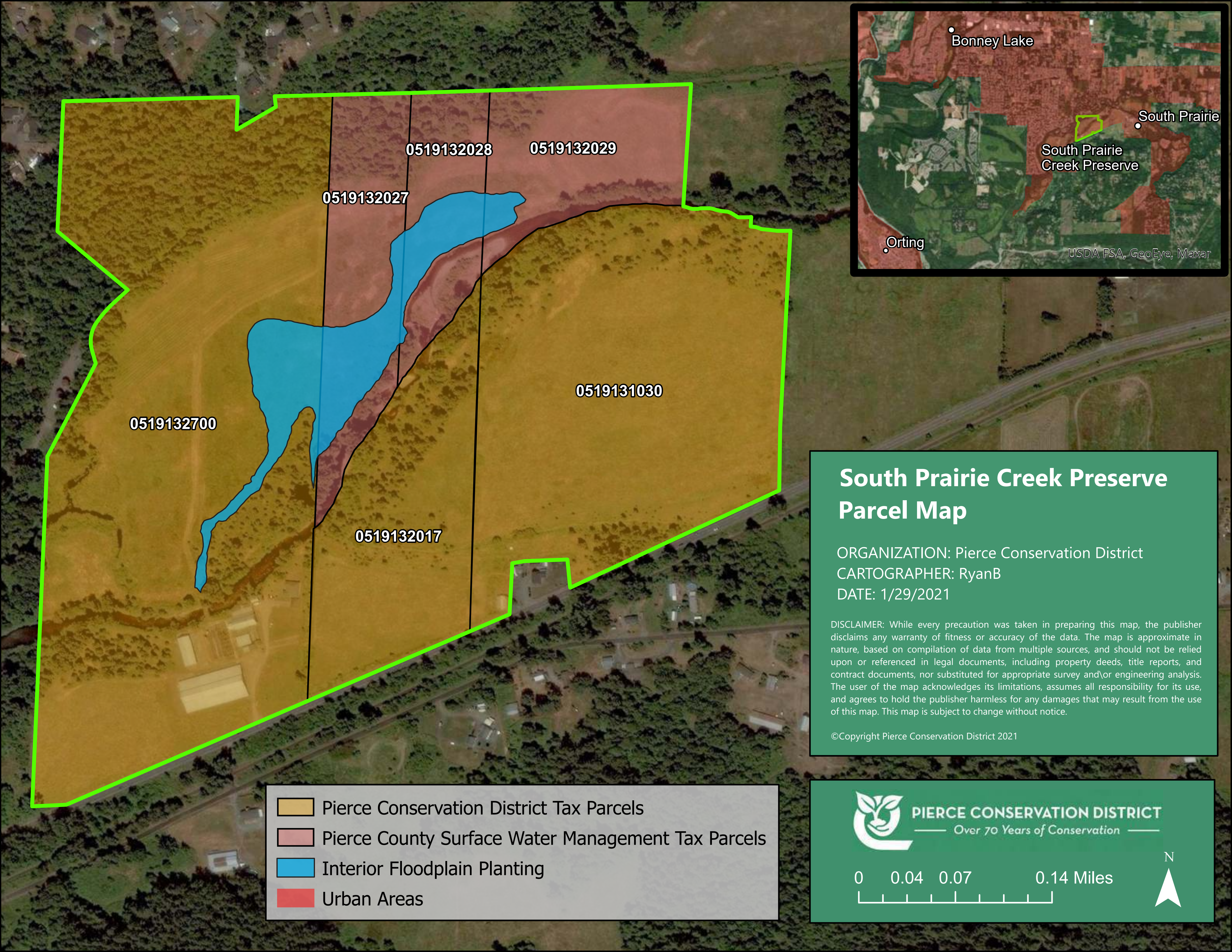
**ADDITIONAL INFORMATION (OPTIONAL)**

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

This planting occurs on contiguous properties totaling 129 acres owned by both Pierce County and the Pierce Conservation District, and the project as a whole is done in partnership with Pierce County, the Puyallup Tribe of Indians, and the South Puget Sound Salmon Enhancement Group. This project is the culmination of a multi-year effort by these partners and others to identify high-priority opportunities to improve endemic salmonid populations, many of which are threatened and endangered.

This planting is part of a larger project to improve salmon habitat and restore floodplain processes in a high priority stretch of South Prairie Creek. Construction of a half-mile side channel and instream improvements to a half-mile of South Prairie Creek are intended to support adult to juvenile out-migrant survival and productivity for spawning, rearing, foraging, migrating, and overwintering life history stages for fall Chinook, Steelhead, Coho, Chum, Pink, and Cutthroat and Bull Trout.

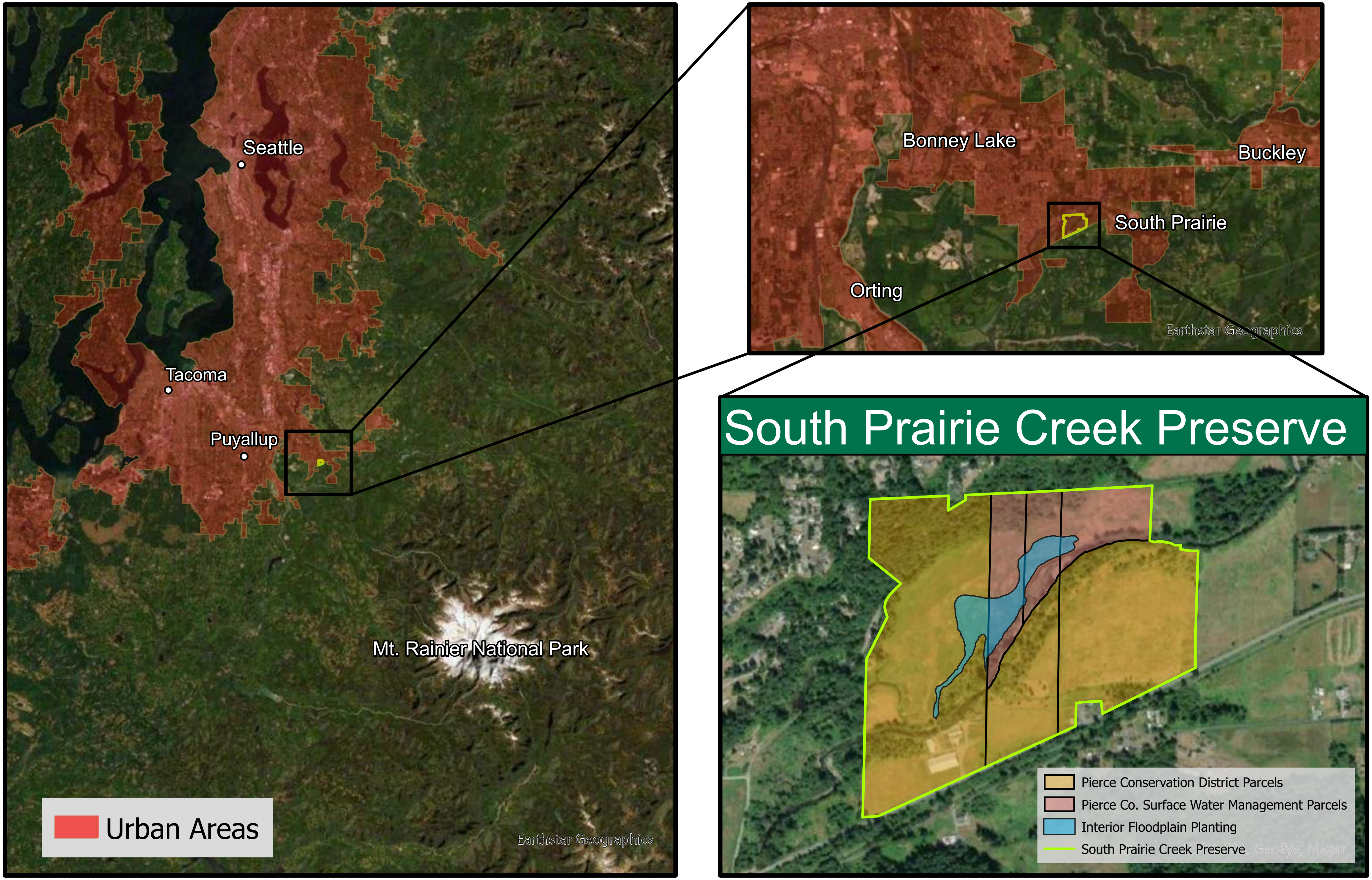
However, the long-term success of this project – and the long-term achievement of self-sustaining ecosystem processes – depends on establishment of riparian and floodplain plant communities throughout the project site.  This planting effort is the final piece of the project. Over time, the trees planted now will provide erosion control; floodplain and riparian habitat and ecosystem processes; shade to lower water temperatures; and contribute to instream habitat diversity, in addition to carbon sequestration.




# South Prairie Creek Preserve Parcel Map

ORGANIZATION: Pierce Conservation District
CARTOGRAPHER: RyanB
DATE: 1/29/2021

DISCLAIMER: While every precaution was taken in preparing this map, the publisher disclaims any warranty of fitness or accuracy of the data. The map is approximate in nature, based on compilation of data from multiple sources, and should not be relied upon or referenced in legal documents, including property deeds, title reports, and contract documents, nor substituted for appropriate survey and\or engineering analysis. The user of the map acknowledges its limitations, assumes all responsibility for its use, and agrees to hold the publisher harmless for any damages that may result from the use of this map. This map is subject to change without notice.




**South Prairie Creek Preserve Vicinity Map**

ORGANIZATION: Pierce Conservation District

CARTOGRAPHER: RyanB

DATE: 2/9/2021



PIERCE CONSERVATION DISTRICT

Over 70 Years of Conservation

0 0.13 0.25 0.5 Miles

N

CITY FOREST CREDITS

**South Prairie Creek Preserve – Interior Floodplain Planting**
**Project Operator Declaration of Planting**

I, the undersigned Project Operator for the Planting Project named "South Prairie Creek Preserve – Interior Floodplain Planting," located at 13518 Pioneer Way E., Orting, WA 98360, and submitted to City Forest Credits by application dated November 10, 2020, declare the following in order to confirm the planting of trees under this Project:

- Trees planted were not required by any law or ordinance to be planted;
- Trees were planted under this project on the following date (s): December 14, 2020 – March 8, 2021;
- The organizations or groups that participated in the planting event(s) are listed in the attached documents (Attachment A);
- Planting events are shown in photos attached, which can include photos of tree stock and planting activities (Attachment B);
- The number of trees planted by species are, to a reasonable certainty, 3065.

These planting numbers are confirmed by one or more of the following supporting and attached documents:

1. Invoices for trees planted, or
2. Invoices or a statement from the party who funded the tree purchase or supplied the trees attesting to the number of trees purchased, or
3. Planting lists compiled contemporaneously with or after the planting event(s) (Attachment C), or
4. Any reporting to the owner or public body regarding the planting, invoices, costs, or other data re the planting, or
5. Any other reliable estimate of trees planted that is approved by the Registry

Signed on March 11 in 2021, by Jayme Gordon, Habitat Improvement Director for the Pierce Conservation District.

Jayme Gordon

Signature

**Attachment A: Organizations or Groups that Participated in the Planting Event(s)**

All plant installation of this project was done by members of the Washington Conservation Corps (WCC). The primary WCC crew responsible for the majority of planting is based with Pierce Conservation District and supervised by Kayla Ink. Another WCC crew, based with Pierce County Surface Water Management (supervised by Amy Compare), assisted with planting on seven days in January 2021.

**Attachment B: Planting Photos**

*Photo (left): WA Conservation Corps member Layne Perkins plants the South Prairie Creek Preserve Interior Floodplain, February 10, 2021.*

*Photo (right): WA Conservation Corps member Gabi Murphy plants the South Prairie Creek Preserve Interior Floodplain, February 10, 2021.*

*Photos (above and below): WA Conservation Corps members install tree protector tubes around the trees planted in the South Prairie Creek Preserve Interior Floodplain, February 24, 2021.*

**Attachment C: Planting List for South Prairie Creek Preserve – Interior Floodplain Planting**

Species eligible for City Forest Credits

| Plant Name (common) | Plant Name (scientific) | Total for Interior Floodplain | Stock |
|---|---|---|---|
| Douglas fir | *Pseudotsuga menziesii* | 110 | bare root |
| Western red cedar | *Thuja plicata* | 800 | bare root |
| Sitka spruce | *Picea sitchensis* | 200 | bare root |
| Black cottonwood | *Populus balsamifera* | 600 | bare root |
| Black cottonwood | *Populus balsamifera* | 50 | 36" live stakes |
| Oregon ash | *Fraxinus latifolia* | 150 | bare root |
| Big leaf maple | *Acer macrophyllum* | 485 | bare root |
| Red alder | *Alnus rubra* | 300 | bare root |
| Black hawthorn | *Crataegus douglasii* | 150 | bare root |
| Vine maple | *Acer circinatum* | 220 | bare root |
| | **Total:** | **3065** | |

CITY FOREST
CREDITS

**Declaration of Planting Affirmation**

I, the undersigned working on behalf of the Washington Conservation Corps at the Washington State Department of Ecology, confirm that tree planting(s) occurred on the following dates under the project named in the City Forest Credits registry "South Prairie Creek Preserve – Interior Floodplain Planting" by the Project Operator, Pierce Conservation District.

Trees were planted under this project on the following date(s): December 14, 2020 – March 8, 2021.

The approximate number of trees planted is: 3065.

| | |
|---|---|
| **Name:** | Kayla Inks |
| **Title:** | Crew Supervisor |
| **Address:** | c/o WA State Dept. of Ecology<br>300 Desmond Dr. S.E., Lacey, WA 98503 |
| **Phone:** | (360) 584-6596 |
| **Email:** | kink461@ecy.wa.gov |
| **Signature:** | |
| **Date:** | 3/10/2021 |

# 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.

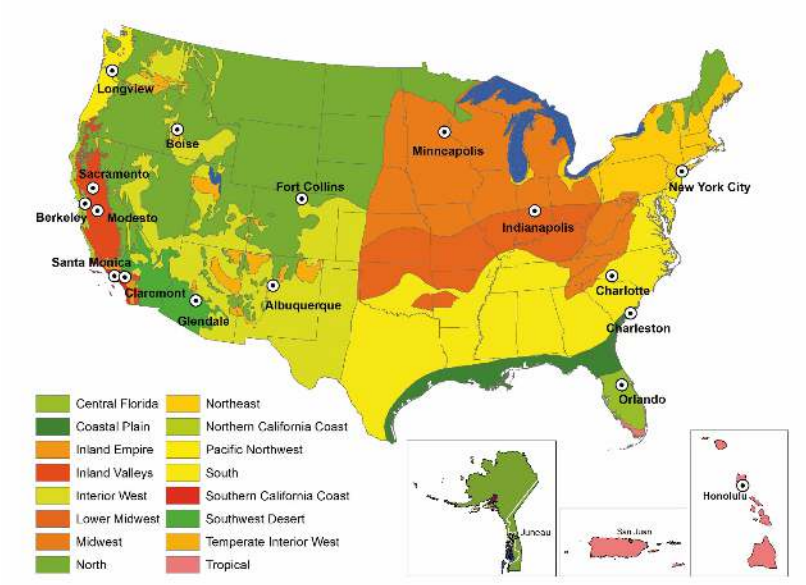


Fig. 1. Climate zones of the United States and Puerto Rico were aggregated from 45 Sunset climate zones into 16 zones. Each zone has a reference city where tree data were collected. Sacramento, California was added as a second reference city (with Modesto) to the Inland Valleys zone. Zones for Alaska,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

Species Assignment by Tree-Type

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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