Urban Forest Tree Planting Carbon Protocol

Draft

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Urban Forest Carbon Registry

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Quick Checklist of Requirements

- ✓ Project Operator identified
- ✓ Signed Implementation Agreement
- ✓ Project in one of the following:
    - Urban Area per Census Bureau maps
    - An incorporated or unincorporated city or town
    - Designated watershed or source water zone overlapping one of above
    - A transportation or utility right of way through one of above
- ✓ Project Operator meets one of following:
    - Owns the land, trees, and credits
    - Has an easement for right of way and owns trees and credits
    - Has a written agreement with landowner to receive carbon credits
- ✓ Project will report for 25 years
- ✓ Documentation (App. A)
- ✓ Project commences on submitting application to Registry
- ✓ Legally required trees <u>not</u> eligible
- ✓ Project seeking:
    - Progress credits (quantify at times of project's choice and seek credits; and quantify at end of 25 years); or
    - Forward credits (seek credits early in project based on projected carbon storage; and quantify at end of 25 years)
- ✓ Understand Reversals
- ✓ Quantification: can use Single Tree Method or Canopy Method (App. B)
- ✓ Verification by Registry, from quantification data submitted by project (App. C)

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Introduction

This Urban Forest Carbon Protocol sets forth the requirements for Tree Planting projects in urban areas in the U.S. to earn certified carbon credits.

This operative part of the Protocol varies from virtually all carbon protocols in that it sets forth the requirements concisely, without the terminology of most carbon protocols. Implementation of urban forest projects requires clarity and pragmatism.

Appendix D of the Protocol contains a detailed discussion of the principles and standards applicable to carbon protocols in general and the development of the specific requirements in this Urban Forest Protocol.

Background to this Urban Forest Protocol

The protocol you are reading arises from the work of the drafters on this protocol as well as the work of scores of people over six years, primarily in the State of California, on two previous protocols. Those two prior efforts taught painful but crucial lessons:

- The protocol must be feasible practically and economically. And it must cover a wide range of urban forest projects. Urban forest projects cannot afford teams of specialists to interpret and implement a complicated protocol.
- Urban forestry requires a protocol that adapts the principles of carbon protocols in general to the unique conditions of urban forestry.

These unique factors for urban forest projects include:

- New tree planting in urban areas is almost universally done by non-profit entities, cities or towns, or quasi-governmental bodies like utilities.
- Except for a relatively small number of wood utilization projects, urban trees are not merchantable, are not harvested, and generate no revenue or profit.
- With the exception of very recent plantings begun in California using funds from its Greenhouse Gas Reduction Fund, no one currently plants urban trees with carbon as a decisive reason for doing the planting.
- Because urban tree planting and maintenance are expensive relative to carbon revenues, urban forestry has not attracted established for-profit carbon developers.

- Because urban forest projects will take place in urban areas, they will be highly visible to the public and easily visited by carbon buyers. This contrasts with most carbon projects that are designed to generate tradeable credits purchased in volume by distant and "blind" buyers.

Urban tree cover is declining across American cities, yet both urban land area and urbanization of the population are growing. There has never been a greater need for an urban forest carbon protocol that balances stringency with the need to deliver to cities and towns the climate and health benefits of one of humankind's oldest companions – the trees.

1. Eligibility Requirements

1.1 Project Operators

A Project requires at least one Project Operator ("PO"), an individual or an entity, who undertakes a Project, registers it with the Urban Forest Carbon Registry (the "Registry"), and is ultimately responsible for all aspects of the project and its reporting.

1.2 Project Implementation Agreement

A Project Operator must sign a Project Implementation Agreement (PIA) with the Registry setting forth the Project Operator's obligation to comply with this Protocol.

1.3 Project Location

Projects must be located within at least one of the following:

A. The Urban Area boundary ("Urban Area"), defined by the most recent publication of the United States Census Bureau (https://www.census.gov/geo/maps-data/maps/2010ua.html);

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. A zone or area designated by any governmental entity as a watershed or for source water protection, provided the designated zone or area overlaps some portion of A, B, or C above;

E. A transportation, power transmission, or utility right of way, provided the right of way begins, ends, or passes through some portion of A, B, C, or D above.

1.4 Ownership and Eligibility to Receive Potential Credits

The Project Operator must demonstrate ownership of potential credits 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 for the Project Duration of any credits for carbon storage or other benefits delivered by Project trees on that landowner's land.

2. Project Duration

[The Registry is working to establish a 40-year buffer (reserve) pool of additional forest carbon to collateralize or insure the urban carbon stored in Project trees. Buyers thus will receive two stocks of CO2, so that even if all urban projects cease after year 25, the forest pool will store the same or more CO2 for 40 years. Details to come.]

Projects must submit Project Reports (at intervals of their choice) to the Registry for 25 years from commencement ("Project Duration"). Projects may earn credits after the 25-year Project Duration as provided in Section 8.

3. Project Documentation, Reporting, and Record-keeping

Documentation, reporting, and record-keeping requirements are contained in Appendix A. All projects must quantify carbon stored and submit a Project Report at the end of the 25-year Project Duration. Projects may seeks credits earlier under Section 6.

4. Project Commencement

A Project commences when the Project Operator submits an application, provided the Registry approves that application within six months of submittal.

5. Legally Required Trees Not Eligible

Trees planted due to an enacted ordinance or law are not eligible.

6. Issuance of Credits for Tree Planting Projects

The Registry will issue Community CarbonGreen Credits™, representing a metric tonne of carbon, bundled with the quantified co-benefits of storm water sun-off reduction, energy savings (cooling), and air quality.

The Registry will issue credits to projects that comply with the requirements of this protocol, as follows:

6.1 Progress Credits

A Project Operator can choose to quantify carbon stored at any time after Year 5 of a tree-planting project and to request verification and issuance of credits by the Registry.

After an issuance of Progress Credits, the credit amount issued shall be the change in carbon stored from the prior issuance of credits.

6.2 Forward Credits

[The Registry is working to establish a 40-year buffer (reserve) pool of additional forest carbon to collateralize or insure the urban carbon stored in Project trees. This forest pool of CO2 will thus insure the CO2 storage represented in a forward credit. Details to come.]

If a Project Operator chooses not to request Progress Credits, the Registry will issue forward credits on the following tiered schedule:

A. After planting of project trees: 10% of projected total carbon stored by Year 26;

B. After Year 3: 40% of projected total carbon stored by Year 26;

C. After year 5: 30% of projected total carbon stored by Year 26;

D. At the end of the 25-year Project Duration and after quantification and verification of carbon stored: “true-up” credits equaling the difference between credits already issued (which were based on projected carbon stored) and credits earned based on quantified and verified carbon stored;

E. 5% of total credits earned will be retained by the Registry at the last issuance of credits to a Project for use in a Registry-wide a Reversal Pool;

Projects can continue after Year 25, and earn credits, as provided in Section 8.

7. Reversals in Tree Planting Projects

All Project Operators must sign a Project Implementation Agreement with the Registry. This Agreement may obligate Project Operators in certain defined circumstances to do the following, among other things: 1) agree to a hold-back or retainage of credits until the expiration of the 25-year Project Duration, upon which the retained credits would be released, or 2) return to the Registry for cancellation credits that have been issued for project trees that are lost and/or 2) forgo future credits in the same amount as those that should have been returned, and/or 3) contribute to a Reversal Pool of credits.

7.1 Reversals in Projects Receiving Progress Credits

A. Tree planting projects that seek Progress Credits shall not quantify carbon stored or request issuance of credits in the first five years of a tree-planting project, when most mortality occurs.

B. A reversal in a project receiving Progress Credits is any decline in carbon stored between the following two points in time:

i. receipt by the project of credits for stored carbon and

ii. final quantification of carbon stored at the end of the project's 25-year Project Duration.

C. If a project shows a decline in carbon stored in subsection 7.1B above, it must return credits equal to the amount of the decline ("Unearned Progress Credits") and forgo issuance of current and future credits until the Unearned Progress Credits are made up.

D. If a Project Operator fails to compensate for Unearned Progress Credits as above, that Operator may be barred from urban forest carbon projects for a specified time period at the discretion of the Registry.

7.2 Reversals in Projects Receiving Forward Credits

A. At the final quantification and true-up of credits at the end of the 25-year Project Duration, the Registry will retain 5% of total credits earned.

B. If a project has received more forward credits than it has earned based on the final quantification and true-up ("Unearned Forward Credits"), it must return credits equal to the amount of those Unearned Forward Credits received and/or forgo issuance of current and future credits until the Unearned Forward Credits are made up.

C. If a Project Operator fails to compensate for a reversal, that Operator may be barred from urban forest projects for a specified time period at the discretion of the Urban Forest Carbon Registry.

8. Continuation of Tree Planting Projects after 25-Year Project Duration

After the minimum 25-year Project Duration, projects may continue their activities, submit Project Reports under Appendix A, and seek issuance of credits under Section 6. Projects must comply with all applicable requirements of this Protocol.

If a project chooses to continue into a Second Project Duration, it can:

A. seek Progress Credits as provided in subsection 6.1, but without the five-year waiting period in that subsection, or

B. seek Forward Credits as provided in subsection 6.2 for its Second Project Duration by re-setting its 25-year Project Duration. During this Second Project Duration, it need not request issuance of credits on the tiered schedule in that subsection, but may request Forward Credits at any time equal to 80% of projected total carbon stored. The remaining 20% of credits shall be accounted for as provided in subsections 6.2 D and E.

9. Quantification of Carbon and Co-Benefits for Credits

The Registry will issue Community CarbonGreen Credits™ to a Project upon request by a Project Operator and verification of compliance with this Protocol. Project Operators must follow the Quantification methods set forth in Appendix B.

Appendix B sets out two methods for quantification, one for single trees and one for tree canopy. Each method requires certain steps, data samples from the Project Operator, data from look-up tables that are or will be provided, and calculations.

Appendix B also provides methods for calculating co-benefits, such as storm water run-off reduction, energy savings, and air quality. And Appendix B sets out a method for projecting carbon storage for Tree Planting projects seeking Forward Credits.

10. Verification

The Registry will issue credits only after a Project Operator submits a Project Report and undergoes verification by the Registry. Credits issued prior to completion of the 25-year project period will be subject to the Reversal Requirements set forth in Section 7.

The Registry will verify compliance with this Protocol per ISO 14064-3 as set forth below and in App. C.

Appendix C sets out verification methods and standards. Here is a summary.

- Verification will be conducted by a verification official at the Registry, with review by a peer reviewer.
- App. C sets out standards for verification, including thoroughness, accuracy, sampling, and other elements, for both the Single Tree Method and the Tree Canopy Method, and for the issuance of Forward Credits. App. C will also contain standards for geocoded photographs, data, or similar landmarking that provides verification of the Project Operator's data on quantification.
- For the Single Tree Method, the Project Operator will provide geocoded photographs with species and DBH (diameter at breast height) for a sample of project trees. The Registry verification official will then confirm that the photographed species and DBH match the data submitted as "recorded in the field" and are consistent with data from the original Project Plan.
- For the Tree Canopy Method, the Project operator will submit to the Registry the i-Tree Canopy file that they developed, including locations used to calculate canopy area. The Registry verification official will use a subsample of these points to independently estimate canopy area for the same project area.
- For projects requesting forward credits on the tiered release in Section 2.3.B, the Project Operator will send to the Registry geocoded photographs of a sampling of project trees or canopy, or provide maps or images from Google Earth or other accepted imaging standards that allow verification of project trees.

- Project Operators may use data from management or maintenance activities regularly conducted if the data was collected within 12 months of the project's request for credits.

Appendix A

Project Documentation, Reporting, and Record-keeping for Tree Planting and Tree Preservation Projects

A.1 Documentation to Submit a Project

Project Operators must provide the following documentation to submit their project to the Registry.

Document	When Submitted	Content Summary
Project Submittal Form	Once, at or within one year of Project Commencement	Project Operator, Location, Summary of Project
Project Plan	Once, with Project Submittal Form or within one year of Project Commencement	Design of Project, Compliance with Eligibility Requirements, Data on Trees for Projections and Quantification per Section ___.
Project Implementation Agreement with the Registry	Once, within one year of Project Commencement	Agreement Binding the Project Operator, specific provisions to come
Signed Affidavit of Land Ownership or Permission per Section ___.	With Project Implementation Agreement, or upon any change in ownership or permission	Affidavit of Project Operator on Ownership of Land or Permission
Signed Affidavit of Compliance	With Project Implementation Agreement	Affidavit of PO on compliance with requirements of protocol

A.2 Documentation for Quantification, Verification, and Request for Issuance of Credits

Project Operators must submit the following documentation on status and to request verification and issuance of credits by the Registry.

Document	When Submitted/Required	Content Summary
Status Reports	Annually, at anniversary of project commencement	One-page report to be filled in confirming Project Operator, operational status, and any significant variations from Project Plan
Project Reports, including quantification of carbon	Always at end of Project Duration. Before that, at Project Operator's discretion, but required before verification or issuance of credits.	Status of Project, Update on Eligibility, project trees for Forward Credits, quantification, and comparison of projected carbon storage with quantified carbon if received Forward Credits.

A.3 Reporting During and at End of Project Duration

A Project Report must be submitted at the end of a project's Project Duration. During a project, the Project Operator may submit a Project Report and seek verification and issuance of credits at any interval chosen by the Project Operator. The Registry will not verify or issue credits without a Project Report.

Project Reports must contain:

a. Any updated information or data on eligibility, and

b. Updated project inventories, data on existence of project trees for issuance of Forward Credits, and any quantification data required by Section 9 and Appendices B or C on quantification and verification.

A.4 Record Keeping

Project Operators shall keep all documents and forms related to the project for a minimum of the 25-year Project Duration. If the Project seeks credits after the 25-year Project Duration, it must retain all documents for as long as it seeks issuance of credits. This information may be requested by the Registry at any time.

A.5 Transparency

The Registry requires data transparency for all Projects, including data that displays current carbon stocks, reversals, and quantification of carbon stored. For this reason, all project data reported to the Registry will be publicly available on the Registry's website or by request.

Appendix B

Quantification Methods for Tree Planting Projects

This Appendix B on Quantification for Tree Planting Projects consists of a Summary of Quantification Steps, followed by a longer section entitled Quantification Methods and Examples, which provides a more detailed walk-though of quantification methods using a sample project.

We are developing several spreadsheet tools that will make using these methods as easy as possible. Users will essentially enter required data in the spreadsheet tool, and the tool will perform the necessary calculations from that data and from tables built into the spreadsheet. We are testing those spreadsheets now and will post them as soon as possible.

Note that quantification methods for Tree Preservation Projects, as distinct from Tree Planting Projects, are contained within the Tree Preservation Protocol.

Summary of Quantification Steps

This section summarizes the steps to quantify carbon storage in tree planting projects. Two different methods are available. Project Operators can select to use the Single Tree Method (where planted trees are scattered among many existing trees, such as street or yard tree plantings) or the Tree Canopy Method (where planted trees are relatively contiguous, such as in park or riparian plantings).

The Single Tree Method requires tracking and sampling of individual trees. The Tree Canopy Method requires tracking of changes in the project's overall tree canopy area. Steps for quantification are presented for Forward Crediting and for use at any time after planting. Appendix B also contains an example for each method, with associated spreadsheet tables and calculations.

Steps for the Single Tree Method

1) Describe the project (i.e., dates trees planted, general locations and climate zone used for calculations).

2) Create a planting list that contains data on the numbers of trees planted by species (with tree-type for each species), location and date. We provide tables for each climate zone that match species with tree-types.
3) Use the Sample Size Calculator that we provide and the Stored CO_2 per Tree Look-Up Table to determine the number of tree sites to sample. We define a "tree site" as the location where a project tree was planted, and use the term "site" instead of "tree" because some planted trees may no longer be present in the sites where they were planted.
4) Randomly sample tree sites collecting data on species, status (alive, dead, removed, replaced), dbh (to nearest inch) and photo of tree site (may be with or without the tree planted) with geocoded location and date.
5) Fill-in the table provided showing the number of live trees sampled in each 1" dbh class by tree-type.
6) Combine data from the step 5 table with the CO_2 Stored by DBH Look-Up Table for your climate zone to calculate CO_2 stored by sampled trees for each tree-type.
7) Fill-in the table provided showing number of sites planted, sites sampled and status of sampled tree sites by tree-type. This table calculates Extrapolation Factors.
8) Combine data from tables in step 7 (Extrapolation Factors) and step 6 to scale-up CO_2 stored from the sample to the population of trees planted.
9) Fill-in the table provided to incorporate error estimates of ±15% to CO_2 stored by the entire tree population.
10) Fill-in the table provided to incorporate estimates of co-benefits.

Forward Crediting – Single Tree Method

1) Fill-in the table provided using data from the Stored CO_2 per Tree Look-Up Table for 25 years after planting and number of trees planted by tree-type. It will apply the 10% deduction to account for likely tree losses and the percentages of credits issued at years 1 (10%), 3 (40%) and 5 (30%) after planting.

Steps for the Tree Canopy Method

1) Describe the project (i.e., dates trees planted, locations and climate zone).
2) Create a planting list that contains data on the numbers of trees planted by species (with tree-type for each species obtained from the table provided).
3) Fill-in the table provided using data from the Stored CO_2 per Unit Canopy Look-Up Table for 25 years after planting and numbers of trees planted by tree-type to calculate the Project Index.
4) Use i-Tree Canopy to calculate total project area and area in tree canopy.
5) In the table provided, multiply the area in tree canopy by the Project Index to calculate total CO_2 stored by trees planted in the project area.
6) Fill-in the table provided to incorporate error estimates of ±15% to CO_2 stored by the entire tree population.

7) Fill-in the table provided to incorporate estimates of co-benefits.

Forward Crediting – Tree Canopy Method

1) Fill-in the table provided using data from the Stored CO_2 per Unit Canopy Look-Up Table for 25 years after planting and the No Loss Tree Canopy value. The No Loss Tree Canopy value is the product of the 25-yr UTC per tree and the number of trees planted by tree-type. The table will automatically apply the 10% deduction to account for likely tree losses and the percentages of credits issued at years 1 (10%), 3 (40%) and 5 (30%) after planting.

Quantification Methods and Examples

There are two different methods for quantifying carbon storage in urban forest carbon projects – the Single Tree Method (where planted trees are few or are scattered among many existing trees) and the Tree Canopy Method (where planted trees are relatively contiguous). The Project Operator (PO) can decide which approach to use.

This Appendix shows steps for quantification of carbon dioxide (CO_2) stored and for co-benefits for hypothetical projects. Also, it illustrates how to use the two methods to forecast carbon storage for the issuance of forward credits.

Single Tree Method
The PO calculates the amount of CO_2 currently stored by planted project trees in metric tonnes (t) on a tree-by-tree basis and calculates the total for all live trees, based on sampling of the resource. The following steps are required and illustrated for a hypothetical planting of 500 street/front yard sites in Sacramento, with 71 trees sampled 25-years after planting.

Step 1. Acquire the following information: numbers of trees planted, date planted, species name and tree-type for each species, gps location and climate zone (Table 1). Tree types: BDL = broadleaf deciduous large, BDM = broadleaf deciduous medium, BDS = broadleaf deciduous small, BEL = broadleaf evergreen large, BEM = broadleaf evergreen medium, BES = broadleaf evergreen small, CEL = conifer evergreen large, CEM = conifer evergreen medium, CES = conifer evergreen small.

Table 1. Planting list for street tree sites in Sacramento, CA (Inland Valley climate zone).

Planting List (Species)	Common Name	Tree-Type	Number Planted	Tree-Type Subtotals
Celtis australis	European hackberry	BDL	45	
Quercus lobata	valley oak	BDL	40	
Ulmus species	elm	BDL	35	120
Jacaranda mimosifolia	jacaranda	BDM	40	
Melia azedarach	Chinaberry	BDM	30	70
Chitalpa tashkentensis	chitalpa	BDS	30	
Diospyros kaki	Japanese persimmon	BDS	20	50
Grevillea robusta	silk oak	BEL	45	
Quercus suber	cork oak	BEL	35	80
Acacia species	acacia	BEM	30	
Eucalyptus cinerea	silver dollar eucalyptus	BEM	25	55
Laurus nobilis	laurel de olor	BES	30	30
Cedrus atlantica	Atlas cedar	CEL	25	
Pinus halepensis	aleppo pine	CEL	25	50
Pinus pinea	Itailian stone pine	CEM	20	
Juniperus species	juniper	CEM	25	45
Total Sites Planted			500	500

Step 2. Measure and record species, status (i.e., alive, standing dead, removed (date), replaced (date/species) and current dbh of live trees (to nearest 1-inch or 2.54-cm) from a sample or census of planted tree sites.

The number of tree sites to sample is derived using the Sample Size Calculator (Fig. 1).

Figure 1. The PO enters project information described below to calculate the sample size necessary to adequately quantify carbon storage.

	Sample Size Calculator*	
Description		**Value**
1) Choose:	**Margin of Error (15% recommended)**	**15%**
2) Choose:	**Confidence level (95% recommended)**	**95%**
3) Enter:	**Total number of project sites**	**500**
4) Enter:	**Mean stored CO2 per tree (kg)**	**1,534**
5) Enter:	**Standard deviation of stored CO2 (kg)**	**832**
6) Enter:	**Expected proportion of tree survival**	**85%**
	Calculated sample size	**76**

* Normally assumes 15% margin of error at a 95% confidence interval.

The PO enters the following information:

1) Choose the margin of error from the drop down menu, 15% is recommended.
2) Choose the confidence level value (%) from the drop down menu, 95% is recommended.
3) The total number of sites - Enter the total number of original sites, in this example 500.
4) Mean stored CO_2 per tree – using Table 2, look-up the mean CO_2 stored by all tree types for the closest age after planting date, in this case 25-years after planting. Enter this number (1,534 kg) into the Sample Size Calculator.
5) Standard deviation of stored CO_2 – using Table 2, look-up the standard deviation of CO_2 stored by all tree types for the closest age after planting date, in this case 25-years after planting. Enter this number (832 kg) into the Sample Size Calculator.
6) Expected proportion of tree survival – estimates of survival rates can be based on project experience or pre-sampling. Enter the proportion (%) of expected tree survival into the Sample Size Calculator, in this case 85% (this can be calculated by dividing the expected or known number of trees that have survived by the total number of trees that were planted and then multiplying by 100). Note: if you do not have an estimate for tree survival, 50% should be entered.

Table 2. The Stored CO_2 By Age Look-Up Table shows kg stored per tree by tree-type for years after planting in Sacramento, CA (Inland Valley climate zone). There is an equivalent table for each of the 16 U.S. climate zones. Values in the highlighted column for 25-year old trees are used in the Sample Size Calculator and Forward Crediting.

CO2 (kg)	BDL	BDM	BDS	BEL	BEM	BES	CEL	CEM	CES		Std.
Age	ZESE	PYCA	PRCE	CICA	MAGR	ILOP	SESE	PIBR2	PICO5	Avg.	Dev.
5	45	251	78	59	24	13	39	13	47		
10	236	725	230	239	133	60	259	203	167		
15	630	1,232	395	570	315	150	761	964	315		
20	1,256	1,735	560	1,062	550	288	1,623	2,021	475		
25	2,127	2,223	721	1,718	824	478	2,912	2,162	640	1,534	832
30	3,243	2,695	877	2,536	1,128	725	4,688	2,265	807		
35	4,595	3,150	1,028	3,505	1,454	1,031	7,006	2,371	974		
40	6,166	3,589	1,174	4,614	1,799	1,400	9,918	2,479	974		

In this example, 76 sites are needed for sampling to achieve a 15% margin of error with a 95% confidence level for the 500 original project sites, 25 years after planting. Because the gps location of each site was taken when the trees were planted, relocating the tree sites is straightforward. The PO randomly samples 76 of the original sites without bias, visiting each site whether a tree is known to be alive, dead or removed. Because each site is numbered she creates a random number list (i.e., RANDBETWEEN function) without duplicates in Excel to identify the sites to sample.

Table 3. Results from Step 2 combined with information from Step 1 indicate that 76 sites were sampled, 19 of the originally planted trees were removed and 57 remained alive (57+19=76). Of the 19 trees that were removed, 17 were replaced with the same tree-type. Hence, the total number of live trees is 74 (57 originals +17 replacements). This example assumes that all replacements survived.

Sample Data	Tree-Type	No. Sites Planted	No. Sites Sampled	No. Removed Trees	No. Live Trees	No. Replaced Trees	Total Live + Replaced Trees
Brdlf Decid Large (>50 ft)	BDL	120	20	4	15	4	19
Brdlf Decid Med (30-50 ft)	BDM	70	10	3	7	3	10
Brdlf Decid Small (<30 ft)	BDS	50	9	3	7	2	9
Brdlf Evgrn Large (>50 ft)	BEL	80	12	2	9	2	11
Brdlf Evgrn Med (30-50 ft)	BEM	55	7	3	4	3	7
Brdlf Evgrn Small (<30 ft)	BES	30	4	1	3	1	4
Conif Evgrn Large (>50 ft)	CEL	50	8	1	7	1	8
Conif Evgrn Med (30-50 ft)	CEM	45	6	2	5	1	6
Conif Evgrn Small (<30 ft)	CES	0	0	0	0	0	0
		500	76	19	57	17	74

Step 3. Record the number of live + replaced trees sampled by tree-type and dbh class (Table 4).

Table 4. This table shows the distribution of the 74 live sampled trees by dbh class. Replacement trees are smaller than the originally planted trees. The initial version of this table is in 1-inch dbh increments, because tree dbh is measured to the nearest 1-inch. The spreadsheet will bin these into 3- and 6-inch dbh classes used to calculate co-benefits.

	Tree-Type	0-3"	3-6"	6-9"	9-12"	12-15"	15-18"	18-21"	21-24"	24-27"	27-30"	Total Number
Brdlf Decid Large (>50 ft)	BDL	2	2	1	4	5	5	0	0	0	0	19
Brdlf Decid Med (30-50 ft)	BDM	3	0	0	0	2	5	0	0	0	0	10
Brdlf Decid Small (<30 ft)	BDS	0	2	2	5	0	0	0	0	0	0	9
Brdlf Evgrn Large (>50 ft)	BEL	1	1	1	0	0	4	4	0	0	0	11
Brdlf Evgrn Med (30-50 ft)	BEM	2	1	0	0	2	2	0	0	0	0	7
Brdlf Evgrn Small (<30 ft)	BES	1	0	1	2	0	0	0	0	0	0	4
Conif Evgrn Large (>50 ft)	CEL	0	1	0	0	0	0	0	0	6	1	8
Conif Evgrn Med (30-50 ft)	CEM	1	0	0	0	0	0	3	2	0	0	6
Conif Evgrn Small (<30 ft)	CES	0	0	0	0	0	0	0	0	0	0	0
		10	7	5	11	9	16	7	2	6	1	74

Step 4. Multiply the number of live trees for each tree-type in Table 4 by the CO_2 Stored by DBH Look-Up Table values in Table 5 below. The amount of CO_2 stored is calculated and shown for sampled live trees in Table 6 below.

Table 5. CO_2 Stored by DBH Look-Up Table. The version of the table shows values in 1-inch dbh increments. There is a separate table for each of the 16 US climate zones.

dbh (cm)	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9	25.4	27.9	30.5	33.0	35.6	38.1
dbh (inches)	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"	12"	13"	14"	15"
Brdlf Decid Large (>50 ft)	1	5	14	30	55	89	135	193	265	351	453	571	708	863	1,038
Brdlf Decid Med (30-50 ft)	3	17	44	85	142	216	309	420	552	704	878	1,073	1,291	1,532	1,797
Brdlf Decid Small (<30 ft)	3	13	34	66	111	169	242	329	432	552	687	840	1,011	1,200	1,408
Brdlf Evgrn Large (>50 ft)	1	6	18	37	64	102	151	212	285	373	475	592	725	875	1,042
Brdlf Evgrn Med (30-50 ft)	1	4	12	26	47	76	114	162	221	291	374	470	580	704	844
Brdlf Evgrn Small (<30 ft)	3	14	37	71	119	182	260	355	466	594	741	906	1,091	1,295	1,519
Conif Evgrn Large (>50 ft)	1	4	11	23	41	66	98	139	188	247	316	395	486	588	703
Conif Evgrn Med (30-50 ft)	1	5	13	28	49	79	118	166	225	295	377	472	580	702	839
Conif Evgrn Small (<30 ft)	1	4	12	25	44	70	104	147	199	261	333	417	513	621	742

dbh (cm)	40.6	43.2	45.7	48.3	50.8	53.3	55.9	58.4	61.0	63.5	66.0	68.6	71.1	73.7	76.2
dbh (inches)	16"	17"	18"	19"	20"	21"	22"	23"	24"	25"	26"	27"	28"	29"	30"
Brdlf Decid Large (>50 ft)	1,233	1,451	1,690	1,953	2,240	2,553	2,891	3,256	3,649	4,069	4,520	5,000	5,510	6,053	6,627
Brdlf Decid Med (30-50 ft)	2,086	2,399	2,738	3,103	3,493	3,910	4,354	4,824	5,323	5,850	6,404	6,988	7,601	8,243	8,914
Brdlf Decid Small (<30 ft)	1,634	1,880	2,145	2,430	2,736	3,063	3,410	3,779	4,170	4,582	5,017	5,474	5,954	6,457	6,983
Brdlf Evgrn Large (>50 ft)	1,227	1,431	1,654	1,896	2,160	2,444	2,750	3,078	3,428	3,802	4,200	4,621	5,067	5,539	6,036
Brdlf Evgrn Med (30-50 ft)	999	1,172	1,361	1,568	1,794	2,039	2,303	2,588	2,894	3,220	3,569	3,941	4,335	4,753	5,194
Brdlf Evgrn Small (<30 ft)	1,764	2,030	2,317	2,626	2,956	3,310	3,686	4,086	4,509	4,955	5,426	5,922	6,442	6,987	7,557
Conif Evgrn Large (>50 ft)	830	970	1,124	1,292	1,475	1,673	1,886	2,115	2,360	2,622	2,901	3,197	3,511	3,844	4,195
Conif Evgrn Med (30-50 ft)	991	1,159	1,343	1,543	1,762	1,998	2,252	2,526	2,819	3,132	3,465	3,819	4,194	4,591	5,011
Conif Evgrn Small (<30 ft)	876	1,024	1,187	1,364	1,557	1,766	1,990	2,232	2,491	2,767	3,062	3,375	3,707	4,058	4,428

Table 6. CO_2 stored for the 74 sampled live trees (kg) (rounded to the nearest whole number)

dbh (cm)	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9	25.4	27.9	30.5	33.0	35.6	38.1
dbh (inches)	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"	12"	13"	14"	15"
Brdlf Decid Large (>50 ft)	0	5	14	0	110	0	0	0	265	351	905	571	1,416	1,726	1,038
Brdlf Decid Med (30-50 ft)	3	17	44	0	0	0	0	0	0	0	0	0	1,291	0	1,797
Brdlf Decid Small (<30 ft)	0	0	0	66	111	0	0	0	865	1,655	1,375	0	0	0	0
Brdlf Evgrn Large (>50 ft)	0	6	0	0	64	0	0	212	0	0	0	0	0	0	0
Brdlf Evgrn Med (30-50 ft)	0	0	25	26	0	0	0	0	0	0	0	0	0	704	844
Brdlf Evgrn Small (<30 ft)	0	14	0	0	0	0	0	355	0	594	741	0	0	0	0
Conif Evgrn Large (>50 ft)	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0
Conif Evgrn Med (30-50 ft)	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0
Conif Evgrn Small (<30 ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	42	96	116	285	0	0	566	1,129	2,600	3,021	571	2,707	2,430	3,678

dbh (cm)	40.6	43.2	45.7	48.3	50.8	53.3	55.9	58.4	61.0	63.5	66.0	68.6	71.1	73.7	76.2	Sample
dbh (inches)	16"	17"	18"	19"	20"	21"	22"	23"	24"	25"	26"	27"	28"	29"	30"	Total
Brdlf Decid Large (>50 ft)	1,233	2,901	3,380	0	0	0	0	0	0	0	0	0	0	0	0	13,915
Brdlf Decid Med (30-50 ft)	4,172	2,399	5,476	0	0	0	0	0	0	0	0	0	0	0	0	15,199
Brdlf Decid Small (<30 ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,072
Brdlf Evgrn Large (>50 ft)	1,227	2,861	1,654	3,793	4,319	0	0	0	0	0	0	0	0	0	0	14,136
Brdlf Evgrn Med (30-50 ft)	999	1,172	0	0	0	0	0	0	0	0	0	0	0	0	0	3,770
Brdlf Evgrn Small (<30 ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,704
Conif Evgrn Large (>50 ft)	0	0	0	0	0	0	0	0	0	2,622	8,702	6,394	3,511	0	0	21,253
Conif Evgrn Med (30-50 ft)	0	0	0	1,543	1,762	1,998	2,252	2,526	0	0	0	0	0	0	0	10,095
Conif Evgrn Small (<30 ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7,631	9,333	10,510	5,336	6,081	1,998	2,252	2,526	0	2,622	8,702	6,394	3,511	0	0	84,145

Step 5. In this step Extrapolation Factors are calculated that are used to scale-up tree numbers from the sample to the population. Calculate the Extrapolation Factor (# sites planted / # sites sampled) for each tree-type (Table 7). Although not required for the carbon calculations, the sample's gross and net survival rates show the significance of replacement plantings. Gross survival is calculated without replacement as:

Gross survival = (# live that were originally planted/#sample sites)*100

Net survival is with replacements = (total live+replaced / #sample sites)*100

Table 7. Of the original planting, sample results indicate that 75% survived (i.e., gross survival rate). With replacements, 97.4% of the sites contained live trees (i.e., net survival rate). The Extrapolation Factor for each tree-type is shown (i.e., for the CEM tree-type it is 7.5 (45/6).

Sample Data	Tree-Type	Number Sites Planted	No. Sites Sampled	No. Live (Original Planting)	Gross Survival (%)	No. Replace-ment Plt.	Total Live + Replaced Trees	Net Survival (%)	Extrap. Factor
Brdlf Decid Large (>50 ft)	BDL	120	20	15	75.0	4	19	95.0	6.00
Brdlf Decid Med (30-50 ft)	BDM	70	10	7	70.0	3	10	100.0	7.00
Brdlf Decid Small (<30 ft)	BDS	50	9	7	77.8	2	9	100.0	5.56
Brdlf Evgrn Large (>50 ft)	BEL	80	12	9	75.0	2	11	91.7	6.67
Brdlf Evgrn Med (30-50 ft)	BEM	55	7	4	57.1	3	7	100.0	7.86
Brdlf Evgrn Small (<30 ft)	BES	30	4	3	75.0	1	4	100.0	7.50
Conif Evgrn Large (>50 ft)	CEL	50	8	7	87.5	1	8	100.0	6.25
Conif Evgrn Med (30-50 ft)	CEM	45	6	5	83.3	1	6	100.0	7.50
Conif Evgrn Small (<30 ft)	CES	0	0	0	0.0	0	0	0.0	0.00
		500	76	57	75.0	17	74	97.4	

Step 6. Apply the Extrapolation Factors from Table 7 to scale-up from the sample to the population for each tree-type (Extrap. Factor * Live Sample Trees = Total Number of Live Trees). Cut and paste the Sample CO_2 Total (kg) from Table 6, and multiply by the Total Number of Live Trees to calculate Grand Total CO_2. Convert from kg to metric tonnes (divide by 1000) (Table 8).

Table 8. This table shows that there are an estimated 487 live trees (Ext. Factors x Live Sample Trees). The amount of CO_2 stored by the 76 sample trees is 84,145 kg, and when converted to tonnes and extrapolated to the population of 487 trees, totals 557.7 t CO_2.

Sample Data	Tree-Type	No. Sites Planted	Extrap. Factor	Live Sample Trees	Total Number Live Trees	Sample CO2 Tot. (kg)	Grand Total CO2 (t)
Brdlf Decid Large (>50 ft)	BDL	120	6.00	19	114	13,915	83.5
Brdlf Decid Med (30-50 ft)	BDM	70	7.00	10	70	15,199	106.4
Brdlf Decid Small (<30 ft)	BDS	50	5.56	9	50	4,072	22.6
Brdlf Evgrn Large (>50 ft)	BEL	80	6.67	11	73	14,136	94.2
Brdlf Evgrn Med (30-50 ft)	BEM	55	7.86	7	55	3,770	29.6
Brdlf Evgrn Small (<30 ft)	BES	30	7.50	4	30	1,704	12.8
Conif Evgrn Large (>50 ft)	CEL	50	6.25	8	50	21,253	132.8
Conif Evgrn Med (30-50 ft)	CEM	45	7.50	6	45	10,095	75.7
Conif Evgrn Small (<30 ft)	CES	0	0.00	0	0	0	0.0
		500		74	487	84,145	557.7

Step 7. Incorporate error estimates and prices to illustrate the range of amount stored and value (Table 9). Sum the tonnes of CO_2 for the three tree-types (Brdlf Decid, Brdlf Evgrn, and Conif Evgrn) and put the totals into Table 9.

Table 9. This summary table shows that with the ±15% error added to the 557.7 t grand total CO_2 stored (see Appendix 1), the actual amount of CO_2 stored is likely to range between 474 t and 641 t. The estimated value, assuming prices of $20 and $40 per tonne, ranges from $9,481 to $25,654.

	t CO2	$ 20.00	$ 40.00
Tree-Type	at 25 yrs	$ value	$ value
Brdlf Decid	212.5	$ 4,250	$ 8,500
Brdlf Evgrn	136.6	$ 2,733	$ 5,466
Conif Evgrn	208.5	$ 4,171	$ 8,342
Total	557.7	$ 11,154	$ 22,308
	CO2 (t)	Total $	Total $
Total CO2 (t):	557.7	$ 11,154	$ 22,308
High Est.:	641.3	$ 12,827	$ 25,654
Low Est.:	474.0	$ 9,481	$ 18,962
± 15% error = ± 10% formulaic ± 3% sampling			
± 2% measurement (see Appendix 1)			

Step 8. Calculate co-benefits (Table 10).

Co-benefits are shown in Table 10 for 487 live trees 25-years after planting. The total annual value of ecosystem services is $13,861, or $27.72 per site (500 tree sites planted). Estimated energy savings ($6,807) are primarily associated with reductions in air conditioning use due to tree shading and climate effects. Rainfall interception and associated stormwater management savings have an estimated value of $3,291. Benefits associated with the uptake of air pollutants by trees (net $3,278) is somewhat offset by BVOC emissions. Avoided CO_2 emissions associated with energy savings is valued at $486 assuming a CO_2 price of $20 per t. These co-benefits are first-order approximations and dollar values may not reflect the most current prices for local environmental and utility services.

Table 10. Co-benefits estimated for the 487 live trees 25 years after planting calculated using the Inland Valley data found in the i-Tree Streets and Design software. i-Tree prices were used, except for CO_2 , which was $20 per tonne.

Resource Units in ( )		Res Units	RU/site	Total $	$/site
Interception (m3)		1,597.0	3.19	$3,291	$6.58
CO2 Avoided (kg, $20/t)		24,289	48.58	$486	$0.97
Air Quality (kg)					
O3		135.35	0.27	$1,493	$2.99
NOx		36.39	0.07	$1,026	$2.05
PM10		86.04	0.17	$1,785	$3.57
Net VOCs		-99.27	-0.20	-$1,026	-$2.05
Air Quality Total		158.52	0.32	$3,278	$6.56
Energy (kWh & kBtu)					
Cooling - Elec.		56,987	113.97	$6,645	$13.29
Heating - Nat. Gas		13,009	26.02	$162	$0.32
Energy Total				$6,807	$13.61
Grand Total				$13,861	$27.72

Forward Crediting – Single Tree Method (Table 11)

This example (Table 11) assumes that the Registry issues forward credits in the amounts of 10%, 40% and 30% at Years 1, 3 and 5 after planting, respectively, of the forecasted CO_2 stored by project trees 25-years after planting. In the example, we deduct 10% of the Stored CO_2 at 25-years after planting to account for likely tree losses. We assume a price of $20 per tonne. The Total 25-year CO_2 Stored value (i.e., grand total of 798.2 t CO_2) was calculated as the product of 90% of the 25-year CO_2 Stored (kg/tree) values from Table 2 and the number of live trees.

Table 11. Forecasted forwarded CO_2 credits based on a 10% deduction from the amount stored 25-years after planting and value assuming $20/t.

	No. Trees	stored (kg/tree)	Tot. 25-yr CO2 stored (t)	10% CO2 (t)	40% CO2 (t)	30% CO2 (t)	10% CO2 ($)	40% CO2 ($)	30% CO2 ($)
BDL	120	2,127	229.7	23.0	91.9	68.9	$ 459	$ 1,838	$ 1,378
BDM	70	2,223	140.1	14.0	56.0	42.0	$ 280	$ 1,120	$ 840
BDS	50	721	32.4	3.2	13.0	9.7	$ 65	$ 259	$ 195
BEL	80	1,718	123.7	12.4	49.5	37.1	$ 247	$ 990	$ 742
BEM	55	824	40.8	4.1	16.3	12.2	$ 82	$ 326	$ 245
BES	30	478	12.9	1.3	5.2	3.9	$ 26	$ 103	$ 77
CEL	50	2,912	131.0	13.1	52.4	39.3	$ 262	$ 1,048	$ 786
CEM	45	2,162	87.6	8.8	35.0	26.3	$ 175	$ 701	$ 525
CES	0	640	0.0	0.0	0.0	0.0	$0	$0	$0
	500		798.2	79.8	319.3	239.5	$ 1,596	$ 6,386	$ 4,789

Tree Canopy Method

The PO estimates the amount of CO_2 currently stored by planted project trees in metric tonnes (t) based on the amount of tree canopy (TC) determined from remote sensing and an index (CO_2 per unit canopy area) that is weighted by the mix of species planted. The following steps are illustrated for a hypothetical planting of 500 tree sites along a creek in Sacramento, CA measured 25-years after planting.

Step 1. Describe the project, quantify the project area, acquire the following information: numbers of trees planted, date planted, species name and tree-type for each species, gps locations and climate zone (Table 1).

The 500 trees were planted 25-years ago along the Bannon Creek Parkway bordered by Azevedo Dr. (west), Bannon Creek Elementary School (north and east) and West El Camino Ave. (south) (Figure 1). The Project Area, shown outlined in red using a Google image in the i-Tree Canopy application, covers 12.5 acres (5.1 ha). The numbers of trees originally planted are shown by species and tree-type in Table 1.

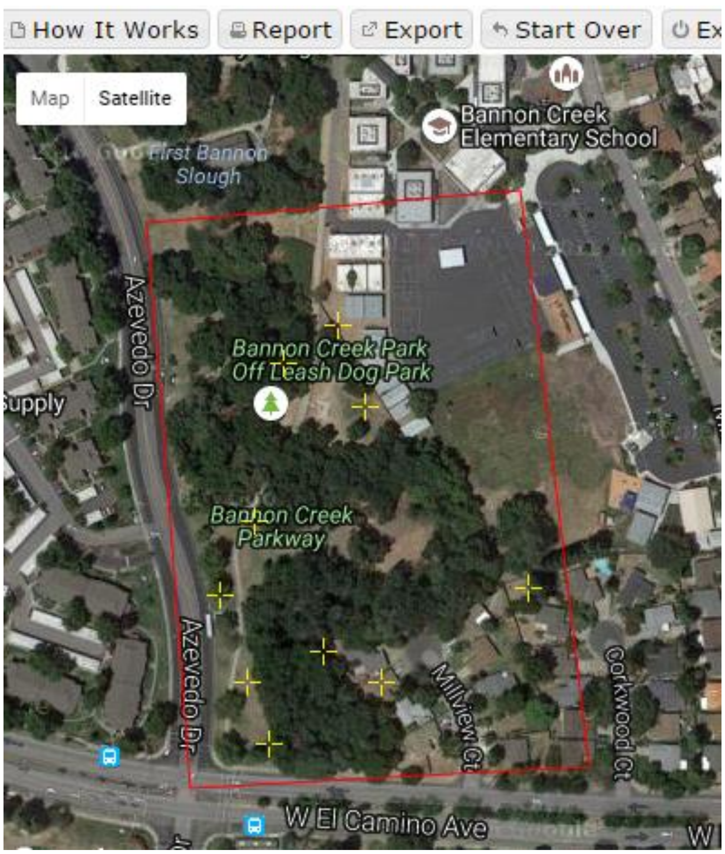

Figure 1. The Project Area where 500 trees were planted 25-years ago in Sacramento, CA.

Table 1. Planting list for trees planted 25-years ago in the Bannon Creek Parkway Project Area, Sacramento, CA (Inland Valley climate zone)

Planting List (Species)	Common Name	Tree-Type	Number Planted	Tree-Type Subtotals
Celtis australis	European hackberry	BDL	45	
Quercus lobata	valley oak	BDL	40	
Ulmus species	elm	BDL	35	120
Jacaranda mimosifolia	jacaranda	BDM	40	
Melia azedarach	Chinaberry	BDM	30	70
Chitalpa tashkentensis	chitalpa	BDS	30	
Diospyros kaki	Japanese persimmon	BDS	20	50
Grevillea robusta	silk oak	BEL	45	
Quercus suber	cork oak	BEL	35	80
Acacia species	acacia	BEM	30	
Eucalyptus cinerea	silver dollar eucalyptus	BEM	25	55
Laurus nobilis	laurel de olor	BES	30	30
Cedrus atlantica	Atlas cedar	CEL	25	
Pinus halepensis	aleppo pine	CEL	25	50
Pinus pinea	Itailian stone pine	CEM	20	
Juniperus species	juniper	CEM	25	45
Total Sites Planted			500	500

Step 2. For each tree-type, locate the Stored CO_2 by Age and Unit Canopy Look-Up Table (Table 2) for the Inland Valley climate zone at, in this case, 25-years after planting. Copy these values into the Project Index Table (Table 3).

Table 2. The Stored CO_2 by Age and Unit Canopy Look-Up Table contains values for each tree-type in the Inland Valley climate zone at 5-year intervals after planting. Values reflect a single tree's CO_2 per unit tree canopy (TC, kg/m_2) at selected years after planting (from McPherson et al. 2016). Values in the highlighted column for 25-year old trees are used in this example.

r TC (kg/m2)	BDL	BDM	BDS	BEL	BEM	BES	CEL	CEM	CES
Age	ZESE	PYCA	PRCE	CICA	MAGR	ILOP	SESE	PIBR2	PICO5
5	2.4	14.3	5.7	4.9	2.6	4.4	6.6	1.2	5.8
10	5.3	17.5	8.6	8.0	5.2	12.0	17.5	5.5	9.4
15	8.0	19.1	11.7	11.0	7.8	19.6	28.6	13.6	12.1
20	10.7	20.3	14.8	14.0	10.3	26.7	40.0	23.5	14.4
25	13.5	21.1	18.0	16.9	12.8	33.1	52.1	24.9	16.4
30	16.2	21.7	21.2	19.8	15.2	38.8	65.0	25.9	18.3
35	18.9	22.3	24.4	22.6	17.5	44.0	79.2	27.0	20.1
40	21.7	22.7	27.6	25.2	19.8	48.8	95.0	28.1	20.1

Step 3. The numbers of trees planted are multiplied by their respective per tree Stored CO_2 index to calculate Project Indices for each tree-type (last column Table 3). These values are summed (10,766 kg) and divided by the total number of trees planted (500) to derive the

Stored CO_2 Project Index (21.53 kg/m^2). This value is the average amount of CO_2 stored per unit of tree canopy (TC), after weighting to account for the mix of species planted.

Table 3. This Project Index Table shows 25-year Project CO_2 indices that are calculated in the fourth column as the products of tree numbers planted (col. 2) and the per tree values for 25-Yr Stored CO_2 (col. 3) from Table 2.

Tree-Type	Number Planted	25-Yr Stored CO2 Indices (kg/m2 TC)	Project Indices (kg/m2 TC)
BDL	120	13.5	1,614.7
BDM	70	21.1	1,475.8
BDS	50	18.0	899.4
BEL	80	16.9	1,355.8
BEM	55	12.8	704.2
BES	30	33.1	992.4
CEL	50	52.1	2,602.5
CEM	45	24.9	1,121.1
CES	0	16.4	0.0
Total:	500		10,766.0
		Project Index:	21.53

Step 4. Use i-Tree Canopy or another tool to classify tree cover and estimate the tree canopy (TC) area for the planted tree sites. If using point sampling, continue adding points until the standard error of the estimate is less than 5%.

Using i-Tree Canopy, 110 points were randomly located in the Project Area (PA) and classified as Tree or Non-Tree. The result was 44.9% tree canopy (TC) and 55.1% non-tree cover, both at ± 4.81% standard error (Std. Er., Table 4). By clicking on the gear icon next to the upper right portion of the image and selecting "Report By Area" the user can prompt i-Tree Canopy to provide an estimate of the area in Tree or Non-Tree cover. In this example, the PA is 12.5 acres.

Table 4. Results from the i-Tree Canopy analysis are percentages of tree and non-tree cover that are converted to area based on the size of the Project Area (PA, 12.5 acres)

	Tree Cover	Non-Tree Cover	Total PA	Std Er.
Percent (%)	44.9	55.1	100	4.81
Area (ac)	5.6	6.9	12.5	
Area (m2)	22,713	27,873	50,585	

Step 5. To estimate the amount of stored CO_2 in the project tree canopy (TC), multiply the Project Index (from Table 3) by the TC area (m^2). Divide by 1,000 to convert from kg to t.

The product of the Project Index (21.53 kg/m^2 TC) and TC (22,713 m^2) is 489,050 kg or 489.1 t CO_2 (Table 5).

Table 5. This table shows that an estimated 22,713 m^2 of tree canopy (TC) stores 489.1 t of CO_2.

	Amounts
Tree Canopy Area (m2)	22,713
Project Index	21.53
Stored CO2 (kg)	489,050
Stored CO2 (t)	489.1

Step 6. Incorporate error estimates and prices to illustrate range of amount stored and value (Table 6).

Table 6. This summary table shows that with 15% of the 489.1 t of CO_2 stored added and subtracted to 489.1 t (see Appendix 1) the actual amount of CO_2 stored is likely to range between 415 t and 562 t. The estimated value, assuming prices of \$20 and \$40 per tonne, ranges from \$8,314 to \$22,496.

	CO2 (t)	$ 20.00	$ 40.00
Total CO2 (t):	489.1	$ 9,781	$ 19,562
High Est.:	562.4	$ 11,248	$ 22,496
Low Est.:	415.7	$ 8,314	$ 16,628
± 15% error = ± 10% formulaic ± 3% sampling			
± 2% measurement (see Appendix 1)			

Step 7. Calculate co-benefits (Table 7).

Co-benefits are shown in Table 7 and based on the ecosystem services produced annually per unit TC. Given the 22,713 m^2 of TC after 25 years, total annual services are valued at \$8,831, or \$18 per site (500 tree sites planted). Estimated energy savings (\$5,354) are primarily associated with reductions in air conditioning use due to tree shading and climate effects. Rainfall interception and associated stormwater management savings have an estimated value of \$2,565. Uptake of air pollutants by trees is somewhat offset by BVOC emissions, resulting in a net benefit of \$532. Avoided CO_2 emissions associated with energy savings is valued at \$380 assuming a CO_2 price of \$20 per t. These co-benefits are first-order approximations and dollar values may not reflect the most current prices for local environmental and utility services.

Table 7. Co-benefits estimated for the 22,713 m^2 of TC at 25 years after planting 500 trees and calculated using the Inland Valley data found in the i-Tree Streets and Design software. i-Tree prices were used, except for CO_2 , which was \$20 per tonne.

Ecosystem Services	Res Units	Total $	$/site
Energy (kWh & kBtu)			
Cooling - Elec.	44,565	$5,196	$10.39
Heating - Nat. Gas	12,679	$158	$0.32
Energy Total		$5,354	$10.71
CO2 Avoided (t, $20/t)	19	$380	$0.76
Air Quality (t)			
O3	0.11	$244	$0.49
NOx	0.03	$168	$0.34
PM10	0.07	$292	$0.58
Net VOCs	-0.08	-$171	-$0.34
Air Quality Total	0.12	$532	$1.06
Rain Interception (m3)	1,245	$2,565	$5.13
Grand Total		$8,831	$17.66

Forward Crediting – Tree Canopy Method (Table 8)

This example (Table 8) forecasts of CO_2 stored in the future tree canopy and assumes that the Registry issues forward credits in the amounts of 10%, 40% and 30% at Years 1, 3 and 5 after planting, respectively. In the example we deduct 10% of the CO_2 stored 25-years after planting to account for likely tree losses. We assume a price of $20 per tonne. The 25-year CO_2 Forecast values (t) were calculated as the product of 90% of the 25-year CO2 Index (kg/m2 TC) values from Table 2 and the No Loss 25-yr TC. The No Loss TC is the product of the 25-yr TC per tree and the number of trees planted.

The 25-year CO2 Forecast (t) values are used to calculate the amount and value of forward credits issued by the Registry assuming a 10% deduction for tree losses. In this example, 90% of the 25-year forecast of CO_2 stored by project trees 25-years after planting is 798.2 t.

Table 8. Forecasted CO_2 credits are based on percentages of amount stored 25-years after planting, assuming a 10% deduction for tree losses and $20/t. The forecasted value of 798.2 t CO_2 stored is the product of the No Loss 25-yr TC (47,140 m^2) and 90% of the 25-yr CO_2 Index (kg CO_2 per m^2 TC). The No Loss TC is the product of the 25-yr TC per tree and the number of trees planted. The No Loss 25-yr TC Forecast is divided by 1000 to convert from kg to tonnes.

Tree-Type	No. Trees	25-yr TC per tree (m2)	No Loss 25-yr TC (m2)	25-Yr CO2 Index (kg/m2 TC)	25-yr CO2 Forecast (t)	10% CO2 (t)	40% CO2 (t)	30% CO2 (t)	10% CO2 ($)	40% CO2 ($)	30% CO2 ($)
BDL	120	158.1	18,967	13.46	229.7	23.0	91.9	68.9	$ 459	$ 1,838	$ 1,378
BDM	70	105.4	7,381	21.08	140.1	14.0	56.0	42.0	$ 280	$ 1,120	$ 840
BDS	50	40.1	2,004	17.99	32.4	3.2	13.0	9.7	$ 65	$ 259	$ 195
BEL	80	101.4	8,112	16.95	123.7	12.4	49.5	37.1	$ 247	$ 990	$ 742
BEM	55	64.4	3,541	12.80	40.8	4.1	16.3	12.2	$ 82	$ 326	$ 245
BES	30	14.4	433	33.08	12.9	1.3	5.2	3.9	$ 26	$ 103	$ 77
CEL	50	55.9	2,797	52.05	131.0	13.1	52.4	39.3	$ 262	$ 1,048	$ 786
CEM	45	86.8	3,905	24.91	87.6	8.8	35.0	26.3	$ 175	$ 701	$ 525
CES	0	39.0	0	16.41	0.0	0.0	0.0	0.0	$0.00	$0.00	$0.00
	500		47,140		798.2	79.8	319.3	239.5	$ 1,596	$ 6,386	$ 4,789

References and Resources

The look-up tables in both examples were created from allometric equations in the Urban Tree Database, now available on-line at: http://www.fs.usda.gov/rds/archive/Product/RDS-2016-0005/. A US Forest Service General Technical Report provides details on the methods and examples of application of the equations and is available online at: http://www.fs.fed.us/psw/publications/documents/psw_gtr253/psw_gtr253.pdf.

The citations for the archived UTD and the publication are as follows.

McPherson, E. Gregory; van Doorn, Natalie S.; Peper, Paula J. 2016. Urban tree database. Fort Collins, CO: Forest Service Research Data Archive. http://dx.doi.org/10.2737/RDS-2016-0005

McPherson, E. Gregory; van Doorn, Natalie S.; Peper, Paula J. 2016. Urban tree database and allometric equations. General Technical Report PSW-253. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA. http://www.fs.fed.us/psw/publications/documents/psw_gtr253/psw_gtr253.pdf

The i-Tree Canopy Tools is available online at: http://www.itreetools.org/canopy/.

Features of ten software packages for tree inventory and monitoring are evaluated in this comprehensive report from Azavea: https://www.azavea.com/reports/urban-tree-monitoring/.

Error Estimates in Carbon Accounting

Our estimates of error include 3 components that are additive and applied to estimates of total CO_2 stored:

Formulaic Error (± 10%) + Sampling Error (± 3%) + Measurement Error (± 2%)

We take this general approach based on data from the literature, recognizing that the actual error will vary for each project and is extremely difficult to accurately quantify. We limit the amount of sampling error by providing guidance on the minimum number of trees to sample in the single-tree approach and the minimum number of points to sample using i-Tree Canopy. If sample sizes are smaller than recommended these error percentages may not be valid. Project Operators are encouraged to provide adequate training to those taking measurements, and to double-check the accuracy of a subsample of tree dbh measurements and tree canopy cover classification. A synopsis of the literature and relevant sources are listed below.

Formulaic Error
A study of 17 destructively sampled urban oak trees in Florida reported that the aboveground biomass averaged 1201 kg. Locally-derived biomass equations predicted 1208 kg with RMSE of 427 kg. Tree biomass estimates using the UFORE-ACE (Version 6.5) model splined equations were 14% higher (1368 kg) with an RMSE that was more than 35% higher than that of the local equation (614 kg or 51%). Mean total carbon (C) storage in the sampled urban oaks was 423 kg, while i-Tree ECO over-predicted storage by 14% (483 kg C) with a RMSE of 51% (217 kg C). The CTCC under-predicted total C storage by 9% and had a RMSE of 611 kg (39%)

Result: Prediction bias for carbon storage ranged from -9% to 14%

Source: Timilsina, N., Staudhammer, C.L., Escobedo, F.J., Lawrence, A. 2014. Tree biomass, wood waste yield and carbon storage changes in an urban forest. Landscape and Urban Planning. 127: 18-27.

The study found a maximum 29% difference in plot-level CO_2 storage among 4 sets of biomass equations applied to the same trees in Sacramento, CA. i-Tree Eco produced the lowest estimate (458 t), Urban General Equations were intermediate (470 t, and i-Tree Streets was highest (590 t).

Source: Aguaron, E., McPherson, E.G. Comparison of methods for estimating carbon dioxide storage by Sacramento's urban forest. pp. 43-71. In Lal, R. and Augustin, B. (Eds.) Carbon Sequestration in Urban Ecosystems. New York. Springer.

Sampling Error
This error term depends primarily on sample size and variance of CO_2 stored per tree. If sample size is on the order of 80-100 sites for plantings of up to 1,000 trees, and most of the trees were

planted at the same time, so the standard deviation in CO_2 stored is on the order of 30% or less of the mean, then the error is small, about 2-4%.

Source: US Forest Service, PSW Station Statistician Jim Baldwin's personal communication and sample size calculator (Sept. 6, 2016)

Measurement Error

In this study the mean sampling errors in dbh measurements with a tape were 2.3 mm (volunteers) and 1.4 mm (experts). This error had small effect on biomass estimates: 1.7% change (from 2.3 mm dbh) in biomass calculated from allometric equations.

Source: Butt, N., Slade, E., Thompson, J., Malhl, Y., Routta, T. 2013. Quantifying the sampling error in tree census measurements by volunteers and its effect on carbon stock estimates. Ecological Applications. 23(4): 936-943.

Appendix C

Verification

[Specific standards for tree preservation projects and certain elements of tree planting projects are being developed and will be coming.]

The Registry will verify compliance with this Protocol per International Standards Organization 14064-3. Specifically, the Registry adopts and utilizes the following standards from ISO 14064-3:

1. Upon receiving a Project Report with updated data on eligibility, quantification of carbon and co-benefits, and a request for credits, the Registry will verify a project's compliance with this Protocol.
2. A peer reviewer will audit the Registry's verification, utilizing standards to be adopted by the Registry.
3. The Registry will verify all sampled trees for both the Single Tree Method and the Tree Canopy Method, as well as for the issuance of Forward Credits.
4. The Registry is developing verification standards for the tree preservation quantification methods and will update this document with that information.
5. The Registry will also adopt standards for geocoded photographs, landmarking, images of trees or canopy areas and any other data necessary to conduct verification.
6. The Registry will develop a database to record, store, and track the quantification and verification data.
7. The Registry will develop a risk assessment standard to provide a cross-check on data collection and review.
8. The Registry will adopt a process for follow-up and maintenance for consistency and continuity.

The following summarizes the basic verification processes:

- Verification will be conducted by a verification official at the Registry, with review by a peer reviewer.
- For the Single Tree Method, the Project Operator will provide geocoded photographs with species and DBH (diameter at breast height) for a verification subsample of sampled Project trees. The Registry verification official will then confirm that the

photographed species and DBH match the data submitted as "recorded in the field" and are consistent with data from the original Project Plan.

- For the Tree Canopy Method, the Project operator will submit to the Registry the i-Tree Canopy file that they developed, including locations used to calculate canopy area. The Registry verification official will independently estimate canopy area for the same project area.
- For projects requesting forward credits on the tiered release in Section 2.3.B, the Project Operator will send to the Registry geocoded photographs of a sampling of project trees or canopy, or provide maps or images from Google Earth or other accepted imaging standards that allow verification of a sample of Project trees.
- The Registry is developing standards for verifying tree preservation projects, including eligibility conditions and quantification under the methods contained in the Tree Preservation protocol. We will publish and post those standards as soon as they are completed.
- Project Operators may use data from management or maintenance activities regularly conducted if the data was collected within 12 months of the project's request for credits.

Urban Forest Carbon Protocols

Appendix D: Discussion of Carbon Protocols and Principles

Draft

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This Appendix D of the protocols contains a detailed discussion of the principles and standards applicable to carbon protocols in general and the development of the specific requirements in the Urban Forest Tree Planting Protocol and the Urban Forest Tree Preservation Protocol.

1. General Standards of Protocol Development

No single authoritative body regulates carbon protocols or determines final standards. The Stockholm Environment Institute's Carbon Offset Research and Education resource lists the various institutions and programs that have set out formulations of basic principles that every carbon offset protocol should contain. (See CORE at http://www.co2offsetresearch.org/policy/ComparisonTableAdditionality.html).

CORE lists twenty-five different programs or institutions that have either developed standards for protocols or issued standards and rules for their own programs. These institutions range from international bodies such as the Kyoto Protocol, the World Resources Institute, and the International Organization for Standardization, to U.S. carbon programs such as the Regional Greenhouse Gas Initiative and Midwest Greenhouse Gas Reduction Accord, to registries such as the American Carbon Registry, the Climate Action Reserve, and the Verified Carbon Standard.

The standards issued by these bodies vary, and the specific rules formulated to give content to these different standards vary even more. For example, the Clean Development Mechanism under the UN Framework stemming from the Kyoto Protocol lists 115 different approved baseline and monitoring methodologies for large scale offset projects.

To complicate matters more, the environmental and carbon community have tolerated a de facto different standard between compliance protocols and voluntary protocols. Compliance protocols exist in cap and trade jurisdictions like California. Because these compliance protocols establish the rules for credits that will offset actual regulated GHG emissions from monitored sources, greater rigor is expected than in voluntary protocols, where purchasers are buying credits voluntarily to reduce their carbon footprint, not to offset regulated emissions.

There is, nonetheless, a general consensus that all carbon offset protocols must contain the following:

- Accounting Rules: offsets must be "real, additional, and permanent." These rules cover eligibility requirements and usually include baselines for additionality, quantification methodologies, and permanence standards.

- Monitoring, Reporting, Verification Rules: monitoring, reporting, and verification rules ensure that credits are real and verifiable.

Certification, enforceability, and tracking of credits and reversals are performed by specific programs or registries, guided by language in the protocol where relevant.

Over the last ten years, several documents setting forth standard and principles for protocols have emerged as consensus leaders for programs attempting to develop their own offset protocols for specific project types. We will follow and refer most often to:

- World Resources Institute/WBCSD GHG Protocol for Project Accounting ("WRI Protocol Guidelines");

- Clean Development Mechanism, Kyoto Protocol, now part of the UN Framework Convention on Climate Change ("CDM").

1.1 Recognition of Distinct Urban Forest Issues in Protocol Development

The task for the Urban Forest Drafting Group was to take the principles and standards set forth in these foundational documents and adapt them to urban forestry. As we described briefly in the Introduction to the Urban Forest Protocols, urban forestry and its potential carbon projects are different than virtually all other types of carbon projects:

- Urban forests are essentially public goods, producing benefits far beyond the specific piece of land upon which individual trees are planted.

- New tree planting in urban areas is almost universally done by non-profit entities, cities or towns, or quasi-governmental bodies like utilities. There are no for-profit entities in the U.S. that engage in new tree planting as their main business.

- Except for a relatively small number of wood utilization projects, urban trees are not merchantable, are not harvested, and generate no revenue or profit.

- With the exception of very recent plantings begun in California using funds from its Greenhouse Gas Reduction Fund, no one currently plants urban trees with carbon as a decisive reason for doing the planting.

- Because urban tree planting and maintenance are expensive relative to carbon revenues, urban forestry has not attracted established for-profit carbon developers.

- Because urban forest projects will take place in urban areas, they will be highly visible to the public and easily visited by carbon buyers. This contrasts with most carbon projects that are designed to generate tradeable credits purchased in volume by distant and "blind" buyers.

The WRI Protocol Guidelines recognize explicitly that the principles underlying carbon protocols need to be adapted to different types of projects. The WRI Protocol Guidelines further approve of balancing the stringency of requirements with the need to encourage participation in desirable carbon projects.

During the drafting process, we remained mindful at all times that the above unique factors of urban forestry distill down to three central attributes:

1. Urban trees deliver a broad array of documented environmental benefits,

2. Urban trees are essentially a public good delivering their array of environmental benefits to the people and communities living in cities and towns – almost 80% of the population, and

3. There are little to no harvests, revenues, or profits for those who preserve and grow the urban forest.

These three key attributes lead to the conclusion that urban forest projects are highly desirable, bringing multiple benefits to 80% of the population in a public good that is unlikely to be gamed or exploited.

Our task then was to draft urban forest protocols that encouraged participation in urban forest projects, while also addressing not just the principles of carbon protocols, but the policies underlying those principles.

2. Additionality

The rationale for additionality is simple: since carbon projects are offsets to emissions, they need to sequester additional carbon, not just give credits for carbon that would have been sequestered anyway.

The policy underpinnings of additionality seek to address two evils: no net carbon reductions and unjust enrichment to those who conduct business as usual.

What follows is an extended discussion of additionality. We begin by returning to the foundational principles and policies underlying the concept of additionality, particularly as set out in the WRI Protocol Guidelines.

We discuss the project-specific methodology and the perverse incentives that methodology creates for urban forestry. We set out the performance standard methodology and apply it to urban forestry, with data and a conclusion. And last, we discuss the legal requirements or regulatory surplus test and apply it to urban forestry.

The Registry is working to establish a 40-year buffer (reserve) pool of additional forest carbon to collateralize or insure the urban carbon stored in Project trees. Buyers thus will receive two full stocks of CO2, so that even if all urban projects cease after year 25, the forest pool will store the same or more CO2 for 40 years. We will provide details on the forest buffer pool as they are developed and finalized.

2.1 Summary of Relevant Portions of the WRI Protocol Guidelines

What follows now is a summary of the guidelines on additionality set forth in the WRI Protocol Guidelines. These guidelines clearly show the flexibility that the WRI intended to build into the development of carbon protocols.

The WRI Protocol Guidelines builds its additionality requirement into its baseline requirement for carbon projects. It also discusses various further or add-on additionality tests, like the legal requirements test, but it states that those additionality tests are entirely discretionary and depend on policy factors within the purview of the project developers. The WRI Protocol Guidelines indicates explicitly the need for flexibility for different project types:

The concept of additionality is often raised as a vital consideration for quantifying project-based GHG reductions. Additionality is a criterion that says GHG reductions should only be recognized for project activities that would not have "happened anyway." While there is general agreement that additionality is important, its meaning and application remain open to interpretation. The Project Protocol does not require a demonstration of additionality per se. Instead, additionality is discussed conceptually in Chapter 2 and in terms of its policy dimensions in Chapter 3. Additionality is incorporated as an implicit part of the procedures used to estimate baseline emissions (Chapters 8 and 9), where its interpretation and stringency are subject to user discretion.

While the basic concept of additionality may be easy to understand, there is no common agreement about how to prove that a project activity and its baseline scenario are different.

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. For example, a focus on environmental integrity may necessitate stringent additionality rules. On the other hand, GHG programs that are initially concerned with maximizing participation and ensuring a vibrant market for GHG reduction credits may try to reduce "false negatives"—i.e., rejecting project activities that are additional—by using only moderately stringent rules.

…There is no agreement about the validity of any particular additionality test, or about which tests project developers should use. ***GHG programs must decide on policy grounds whether to require additionality tests, and which test to require. Because their use is a matter of policy, the Project Protocol does not require any of these tests.***

As the language above makes clear, additionality does not have to be applied on a project-specific basis. In fact, additionality is not a rule to be applied inflexibly, but rather a concept to be developed and adjusted for the context of each type of carbon project. The baseline methodology set out by the WRI allows for that kind of customization.

Given that we are developing two stocks of additional CO2, with the forest stock insuring or buffering the urban stock, we could develop a weak additionality test for the urban protocol. But we have developed a performance standard baseline using a method explicitly authorized by and set forth in the WRI Protocol Guidelines as an alternative to the project-specific test, and also a legal requirements test.

2.2 Project-Specific Methodology

Many people think of additionality as applied only on a project-specific basis, with the specific project or specific project developer being required to show that it reduced emissions (or removed them from the atmosphere) beyond its business-as-usual practices.

In the urban forest context, this produces immediate anomalies:

- Entities with a commitment to or even recent practice of tree planting and who begin carbon projects would get far fewer carbon credits than entities with no historical commitment to urban trees. To use the language of baselines, the baseline of entities that plant trees would be the trees they have annually planted, while the baseline of entities that plant no trees would be zero.

- The City of Los Angeles has launched its Million Tree LA initiative (now CityPlants). These voluntarily planted trees would generate no carbon credits for LA, whereas a city like Bakersfield, which plants few to no trees, would get carbon credits for every tree it planted.
- The same result obtains for an entity like the Sacramento Municipal Utility District, which voluntarily plants over 15,000 trees per year.
- If additionality is applied inflexibly on a project-specific basis, then entities that plant trees now would have the perverse incentive to stop their planting, even temporarily, to bring their own business-as-usual baseline to zero.

- Governments with progressive tree ordinances or land use regulations that seek to increase canopy cover, would get fewer carbon credits because trees planted per their regulations would be part of their baseline and thus not eligible for crediting. Inflexible application of this "legal requirements" test leads to the perverse incentive for cities to leave their trees unregulated and unprotected.

2.3 Performance Standard Methodology

But there is a second additionality methodology set out in the WRI 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 standard using the data from similar activities over geographic and temporal ranges justified by the developer.

We understand that a common perception is that projects must meet a project specific test. Project-specific additionality is easy to grasp conceptually. The CAR urban forest protocol essentially uses project-specific requirements/methods.

But the WRI GHG Protocol for Accounting clearly states that <u>either</u> a project-specific test or a performance standard baseline is acceptable. One key reason for this is that regional or national data can give a <u>more accurate</u> 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 context ignores all other data surrounding that project or entity. And that regional picture may be more accurate than one project or entity.

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 is negative regardless of what one active project or entity is doing.

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

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

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.

A. Data on Tree Canopy Change over Time in Urban Areas

Our 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:

Changes in Urban Tree Canopy (UTC) by Region (from Nowak and Greenfield, 2012)

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

Absolute change is based on city land area
Relative percent change is based on percentage of UTC
Average annual change in UTC in hectares per year
Average annual change in UTC in hectares per capita per year

These data show that urban tree canopy is experiencing negative growth in all four regions. In other words, the urban tree canopy is shrinking. Even though there may be individual tree planting activates that increase the number of urban trees within small geographic locations, the urban tree canopy is declining in all cities but one in this data set, and is declining in every region.

The regional baselines from this data provide baselines for all projects within those regions. The Drafting Group did not use negative baselines for the Tree Planting Protocol, but determined to use baselines of zero.

Our deployment of the Performance Standard baseline methodology for an Urban Forest 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 trees are planted now with carbon as a decisive factor, urban tree planting done to sequester and store carbon is additional;
- Because virtually all new 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 UF carbon projects.

2.4 Legal Requirement Test (also called the Regulatory Surplus Test)

The WRI Protocol Guidelines discuss the so-called Legal Requirement Test. This is identified in the UN's Clean Development Mechanism as the Regulatory Surplus Test. These tests disqualify any credits for carbon stored to meet a pre-existing legal requirement. In other words, the carbon stored must be surplus to carbon stored per legal or regulatory requirements.

If these tests are applied literally, then any tree planted per a city ordinance or code for any reason, such as shade trees for parking lots, would not be additional. But in fact, the WRI

Protocol Guidelines state clearly that application of the Legal Requirement Test is optional. Among the factors relevant to that decision are policy considerations such as other co-benefits from a project or whether a too-stringent application of the test will limit participation in the protocol. Give the documented co-benefits of urban trees, including potential environmental justice, and given the national decline in tree canopy, there is a persuasive case for eschewing the legal requirements test altogether.

But the Drafting Group determined that the Urban Forest Tree Planting Protocol should declare ineligible trees that are planted due to an enacted ordinance or law. Some cities have policies of replacing trees on public property, but these policies are advisory and do not rise to the compulsion of an enacted ordinance.

Our development of a legal requirement test that declares ineligible trees required by ordinance or law to be planted is supported because the baseline of the urban tree canopy is negative.

Moreover, the WRI Protocol Guidelines explicitly allow a balancing of stringency with the need for participation in desirable project types. Given the many environmental benefits of urban trees, delivered to the 80% of the population that lives in cities and towns, our legal requirements test is appropriate.

2.5 Additionality in the Tree Preservation Protocol

Our Drafting Group modeled the Tree Preservation Protocol on the "Avoided Conversion" type of project for forest land. We have provided that urban trees that are under threat of removal, and that are protected from removal, should be eligible to earn carbon credits.

The Avoided Conversion model that we borrowed from the forest context rests on a simple and common sense idea. Forested parcels that are protected from development are additional in that they would have been removed by the development. Therefore, the owners of that protected land should be able to earn carbon credits for those trees protected from development.

Additionality per se is generally not in dispute in forest Avoided Conversion projects. The trees that would have been cut down for development are saved, therefore they are additional from the time they are preserved from development. Every day they are protected from removal is an additional day of CO_2 storage in those trees.

But the simple idea of avoided conversion has proven difficult to capture in the rules of most forest Avoided Conversion protocols. For it is based on two real-world problems. First, proving that trees would be lost to development is counter-factual. How can a project developer show something that has not happened but that is supposed to be imminent and inevitable? If the land ends up being protected from development such that it could qualify for avoided conversion carbon credits, then development of the land could not have been inevitable after all.

This counter-factual predicament is magnified by the failure of most forest Avoided Conversion protocols to identify and define the two key underlying elements of a threat of conversion, which are imminence and inevitability. Because these two key parts of the threat of conversion are not clearly identified and addressed, the rules can become either too vague or overly detailed.

Second, for the Avoided Conversion forest protocol to be consistent with general carbon protocol principles, a project developer should show not only that the land would have been developed, but also that it was saved from development for the carbon storage of the trees on it. If the land was saved for reasons other than carbon storage, then that storage and those carbon credits would not be additional. Yet, we are not aware of an Avoided Conversion forest protocol that addresses this issue.

What does seem clear in both the forest and the urban forest context is that any tree preserved from removal is additional. And the CO2 stored in those preserved trees is additional for as long as those trees are standing.

Moreover, we know from the baseline data utilized to develop the performance standard that urban tree cover is declining. The baseline is negative. This means that the difference between the negative baseline and zero is all additional. For the Tree Planting Protocol, the Drafting Group decided to use a baseline of zero, in effect ignoring the negative baseline. But for Tree Preservation projects, the negative baseline adds support for the additionality of any tree preserved. Any tree protected from removal within the delta of the negative baseline and zero is additional.

As with the forest Avoided Conversion protocols, we have not tried to parse the meanings of imminence and inevitability. Doing this seems more important for forest projects, because forest lands have widely varying threats of removal. Forest land near rural cities or towns is at much higher risk than forest land remote from human settlement.

Most urban trees on private property, by contrast, are under a continual background threat. The simple but inexorable force of land values in urban areas often gives a higher value to land with built improvements than bare land with trees. The only workable tools to mitigate this threat of removal are public ownership of land, laws protecting urban trees from removal during development, and some form of financial incentive, such as carbon revenues, to preserve urban trees.

For purposes of the Urban Forest Tree Preservation Protocol, we follow the Avoided Conversion forest protocols in that we do not define imminence or devise a set of rules to demonstrate it per se. Rather, we set out the protections required to preserve trees from removal or conversion. We also set out a list of factors that a Project Operator could select from to show the threat of conversion. These factors include a threshold land price, perimeter development, and highest and best use studies.

If a project operator shows a threat of removal under the protocol, then the trees preserved from removal are additional from the day they are preserved.

3. Permanence

Permanence embodies the principle that carbon stored should not be reversed. Here is the WRI Protocol Guidelines summary of Permanence:

Emission reductions or removals are permanent if they are not reversible; that is, the emissions can't be rereleased into the atmosphere. The issue of permanence applies to projects where emissions are sequestered in ways that could be reversed over time, such as in forests (which can release carbon through fires or decay) and through geological sequestration (where gases could potentially leak unexpectedly). *There are mechanisms to account for or reduce the risk of reversal, though they can bring additional costs. These include buying insurance in case of emissions reversals, establishing a reserve "buffer" pool of credits or issuing temporary credits from the project that are valid for a period of time but must be re-certified or replaced in the future.* [Emphasis supplied]

The above language specifically refers to "buying insurance," creating a buffer or reserve pool, and even issuing temporary credits. The Registry is working to establish a 40-year buffer (reserve) pool of additional forest carbon to collateralize or insure the urban carbon stored in Project trees. This buffer or reserve pool will act as insurance or collateral for forty years for the urban carbon stored in planting projects under the Registry.

3.1 Time Period

This statement makes no reference to a time requirement for permanence. Rather, the permanence requirement focuses on reversals. This makes sense, because if carbon storage is never reversed, then no time period is necessary. But few human efforts are "never" reversed or truly permanent.

So, the Climate Action Reserve, to take one example, follows the IPCC lead and imposes a 100-year permanence requirement on all of its protocols, with reversal mechanisms for projects that receive progress credits before their 100-year period. But even 100-year carbon storage is not permanent, and carbon stored for those 100 years has no guarantee of staying stored at the end of the 100 years.

Other protocols have adopted a 40-year project duration, preferring to use terms like "Minimum Project Commitment" rather than Permanence. (see Improved Forest Management on American Carbon Registry, for example) The Regional Greenhouse Gas Initiative was willing to accept a 40-year permanence period for its offset projects. Still others have developed risk calculators or assessments, with a sliding scale of "permanence."

So it is clear that many developers of protocols have struggled to create a permanence requirement. The 100-year period of the Climate Action Reserve and the 40-year period of the American Carbon Registry and RGGI are two examples. But it is difficult to reconcile the 60-year difference between these two duration requirements.

In our Tree Preservation Protocol, we require a 40-year preservation commitment, shown either in an easement or, for trees on public lands, a management or protected status for forty years.

For tree planting projects, we had to use a shorter time period and find a different solution to this issue. Our solution is to establish a 40-year buffer or collateral pool of CO2 to back up all of the urban CO2 stored in urban forest planting projects. Because the urban CO2 is backed up for 40 years, we can then set a project duration that will work for urban forestry – 25 years. The years past 25 will result in the greatest CO2 storage, so projects have a strong incentive to continue.

The Drafting Group felt strongly that, because most urban forest projects are funded and executed by cash-short cities and towns and local non-profits, a 40-year commitment will render the protocol unusable. Even a 25-year duration may eliminate worthy projects. But in any event, the CO2 stored in 25-year urban projects is backed up for 40 years.

Some of the unique factors of urban forestry support our method of addressing the permanence issue:

- No one harvests the urban forest, so there is no danger of a Project Operator choosing to terminate its carbon project to reap the profits of harvest. Termination of a forest project for harvest, on the other hand, is a quite real danger where owners are continually assessing the costs and revenues of carbon storage against the profits of harvest.

- With no threat of harvest looming, an urban tree that survives into its second or third decade has a strong probability of surviving for many more years.

- If an urban forest carbon project receives credits for carbon storage at year 15, for example, the carbon storage will grow as the trees grow, so that incidental mortality will likely not lower the carbon stored in that project.

- It is highly unlikely that an entire urban forest will be destroyed by a fire or disease, as can happen with forest land. Most cities have a diversity of species that would mitigate the effect of a disease that afflicted a species.

- Urban forests need to have diversity of species and age, as well as functional diversity. Different species perform certain functions better than others (reducing pollution, providing certain health benefits), and a diverse and healthy urban forest needs to reflect that functional diversity as well as age and species.

- Urban trees are expensive to plant and maintain. Even if urban forest credits commanded a price of $20 per tonne, carbon revenues will likely defray only 5 to 30% of the costs of planting and maintaining a tree. Given the many benefits of urban trees beyond carbon storage, a permanence period must not be so long as to choke participation in these important projects.

- Dynamic land uses and property ownership in cities and towns makes a long permanence period impossible.

- A significant percentage of urban forest funding decisions are made by elected officials. We may hope that our elected officials have a long-term view of our cities and towns, but all too often the time horizon of elected officials is the election cycle. A long permanence period will dramatically discourage most elected officials from promoting participation in urban forest carbon projects.

- Many analysts predict that renewable energies will overtake fossil fuels in 20 years. If that is the case, our permanence goal would be a bridge to those renewable energy sources in 20 years.

For all of these reasons, our Drafting Group determined that a 25-year Project Duration period was the best time period to adapt the principles underlying the permanence standard to urban forestry. We believe that most projects will continue long past the 25-year Project Duration. Projects have every incentive to do so, because they could earn carbon credits after that period, having already invested in making a project successful for its first 25 years.

We have also included specific rules on reversals, so that credits reflecting carbon stored must be earned or compensated.

4. Issuance of Credits

With respect to the issuance of credits, our urban forest protocols break ranks with most carbon protocols and registries in a significant way:

- We will issue so-called Forward Credits; i.e., we will issue credits early in projects, before carbon has been actually stored and quantified.

We understand the strong antipathy for forward credits and the reasons underlying that antipathy. But with the urban CO2 fully backed up by forest CO2 for 40 years, the Forward Credits we issue will be completely insured. The Forward Credits will be fully secure because the credits are fully buffered or collateralized in a duplicate stock of CO2.

Here are the reasons we have developed Forward Credits and why they make sense for both projects and carbon buyers.

4.1 Forward Credits

Forward credits in an urban forest tree planting protocol are not merely desirable, they are indispensable. Almost no urban forest projects can wait for 25 years to receive funding. Elected and agency officials are all too often required to plan with the timeline of an election cycle, not a Permanence standard in a carbon protocol and not a 25-year waiting period for tree growth and carbon storage.

So our challenge was to develop a forward crediting method that would provide assurance to carbon buyers that the carbon reflected in a Forward Credit would be stored. We needed to find a way to show the buyers that any Forward Credits issued are, in effect, guaranteed.

We note first that our society has developed many mechanisms analogous to a Forward Credit where a person or entity receives money or something of value, and then performs a service or pays that money back over time:

- A bond issuer receives the proceeds of a bond in year 1, and then pays that bond back over time.

- A homeowner receives mortgage loan proceeds to purchase a house, and then occupies the house while paying back the mortgage loan over time.

- A contractor receives partial payment before beginning work, and delivers the service over time.

- A landlord receives rent at the beginning of a month and delivers a habitable swelling unit over the next month.

In all these examples, and many more, the parties have agreed to an early delivery of money in exchange for some type of performance later. They have dealt with the risk of later nonperformance by negotiating mechanisms that reduce that risk to acceptable levels. A mortgage lender, for example, requires a minimum loan to value ratio and also a security interest or deed of trust on the property purchased with the loan proceeds. With these in place, the lender has reduced its risk to acceptable levels. Similarly, a bond holder receives less interest the higher the credit rating of the bond issuer and the bond. The bond holder in effect pays more for a more secure promise of later performance.

The large carbon registries have been wary of early issuance of credits, because they have been justifiably worried that carbon developers will take the money and run; i.e., that the carbon developers will not perform their promise to store carbon after credits have been issued.

Our task for the urban forest protocol then, given that we need to issue Forward Credits to make urban forest carbon projects possible, was to analyze potential urban forest carbon projects to determine where the risks were. Where and what, we asked, are the risk points in urban forest projects? Where could projects fail, or be abandoned? And how can we assure performance or coverage around those risk points, so that a Forward Credit is essentially guaranteed to do what it promises, which is to store carbon for a defined time period.

A. Risk Points

Here are the risk points we identified in tree planting projects:

- Will the Project Operator plant the trees?

- Will the trees survive past year 3, given that mortality is higher in the early years of an urban tree's life than in later years?

- Will the trees survive past year 5, given that data supports the conclusion that mortality drops significantly after year 5?

- Are there risk points for large scale mortality due to disease, fire, natural disaster, and other events?

- Is there a risk that the Forward Credits issued will represent more carbon than is actually stored in project trees by the end of the project?

To address the first three and the fifth of these risk points, we developed a tiered or staircase release of Forward Credits, triggered by a Project Operator's demonstration that it has passed particular risk points:

1. After planting of project trees: 10% of projected total carbon stored by Year 26;

2. After Year 3: 40% of projected total carbon stored by Year 26;

3. After year 5: 30% of projected total carbon stored by Year 26;

4. At the end of the 25-year Project Duration and after quantification and verification of carbon stored: "true-up" credits equaling the difference between credits already issued (which were based on projected carbon stored) and credits earned based on quantified and verified carbon stored;

5. 5% of total credits earned will be retained by the Registry at the last issuance of credits to a Project for use in a Registry-wide Reversal Pool;

Forward Credits are thus released only after a project successfully passes through a risk point. And 10% of projected credits are withheld until the end of the project, when a true-up of Forward Credits with carbon stored occurs.

The fourth risk point – fire, disease or some cataclysmic event – we consider remote. A forest fire can sweep through a large stand of forest. But urban fires rarely consume large areas. Some diseases, like Dutch Elm Disease, can over time devastate a species, but most cities have learned the lessons of Dutch Elm Disease and plant a variety of species. Nonetheless, to insure against that unlikely risk of cataclysm, we have provide for retention of 5% of credits earned in a Buffer Pool, to be held by the Registry.

As final and tertiary level of absolute assurance, we repeat that we are working to establish a pool of forest CO2 as a buffer or collateral pool to back up the Forward Credits. This buffer pool will provide a third layer of protection for any buyer concerned that an urban forest project will not store the CO2 promised.

5. Quantification

Quantification methods for Tree Planting projects are set out in Appendix B. The two methods are the Single Tree Method, for smaller projects or trees planted non-contiguously, and the Tree Canopy Method, for trees planted in groups.

We are very close to finalizing spreadsheet tools for both the Single Tree and Canopy Methods that make using the quantification methods as easy as possible. Users will simply enter data in progressive sheets of the spreadsheets, and the spreadsheets will perform the appropriate calculations to give totals. We will create 16 versions of each of these spreadsheet tools, so each of the 16 climate zones will have a tool for each method.

Quantification methods for tree preservation projects are set out in Section 10 of the Tree Preservation Protocol. This 5-step process essentially uses forest and soil carbon quantification, with deductions for a baseline of trees that would have remained even if the land had been developed and for displaced development.

6. Verification

We have set out the basic outlines in the protocols and in Appendix C on Verification, and we will add more detail on verification of both planting and preservation projects in the near future.

Verification is yet another area where the reality of urban forest projects collides with customary practice at large carbon registries and large carbon projects. The scale of the large carbon projects, and the potential revenues, allows for the costs of third-party verification, usually done by professional firms whose fees are substantial.

It was clear to the Drafting Group that many urban forest projects would not be able to afford to pay the substantial fees charged by third-party verification firms. The third-party verification fees would be the single largest expense of many urban forest carbon projects and would cannibalize the revenues.

Rather than impose verification costs on individual projects, we developed and are refining a verification method at the program level. As the protocols and Appendix C set out, we will perform verification at the Registry level, using the standards in ISO 14064-3. The use of geocoded photographs and updated images will help reduce the costs of verification to a manageable level.

We will supplement this discussion as we develop specific requirements and standards for each project type.

Urban Forest Tree Planting Carbon Protocol

Draft

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Quick Checklist of Requirements

- ✓ Project Operator identified
- ✓ Signed Implementation Agreement
- ✓ Project in one of the following:
    - o Urban Area per Census Bureau maps
    - o An incorporated or unincorporated city or town
    - o Designated watershed or source water zone overlapping one of above
    - o A transportation or utility right of way through one of above
- ✓ Project Operator meets one of following:
    - o Owns the land
    - o Has an easement for right of way
    - o Has a written agreement with landowner to receive carbon credits
- ✓ Project will report for 25 years
- ✓ Documentation (App. A)
- ✓ Project commences on submitting application to Registry
- ✓ Legally required trees on private property <u>not</u> eligible
- ✓ Project seeking:
    - o Progress credits (quantify at times of project's choice and seek credits; and quantify at end of 25 years); or
    - o Forward credits (seek credits early in project based on projected carbon storage; and quantify at end of 25 years)
- ✓ Understand Reversals
- ✓ Quantification (App. B)
- ✓ Verification by Registry, from quantification data submitted by project (App. C)

TABLE OF CONTENTS

Introduction

This Urban Forest Carbon Protocol sets forth the requirements for Tree Planting projects in urban areas in the U.S. to earn certified carbon credits.

This operative part of the Protocol varies from virtually all carbon protocols in that it sets forth the requirements concisely, without the terminology of most carbon protocols. Implementation of urban forest projects requires clarity and pragmatism.

Appendix D of the Protocol contains a detailed discussion of the principles and standards applicable to carbon protocols in general and the development of the specific requirements in this Urban Forest Protocol.

Background to this Urban Forest Protocol

The protocol you are reading arises from the work of the drafters on this protocol as well as the work of scores of people over six years, primarily in the State of California, on two previous protocols. Those two prior efforts taught painful but crucial lessons:

- The protocol must be feasible practically and economically. And it must cover a wide range of urban forest projects. Urban forest projects cannot afford teams of specialists to interpret and implement a complicated protocol.
- Urban forestry requires a protocol that adapts the principles of carbon protocols in general to the unique conditions of urban forestry.

These unique factors for urban forest projects include:

- New tree planting in urban areas is almost universally done by non-profit entities, cities or towns, or quasi-governmental bodies like utilities.
- Except for a relatively small number of wood utilization projects, urban trees are not merchantable, are not harvested, and generate no revenue or profit.
- With the exception of very recent plantings begun in California using funds from its Greenhouse Gas Reduction Fund, no one currently plants urban trees with carbon as a decisive reason for doing the planting.
- Because urban tree planting and maintenance are expensive relative to carbon revenues, urban forestry has not attracted established for-profit carbon developers.

- Because urban forest projects will take place in urban areas, they will be highly visible to the public and easily visited by carbon buyers. This contrasts with most carbon projects that are designed to generate tradeable credits purchased in volume by distant and "blind" buyers.

Urban tree cover is declining across American cities, yet both urban land area and urbanization of the population are growing. There has never been a greater need for an urban forest carbon protocol that balances stringency with the need to deliver to cities and towns the climate and health benefits of one of humankind's oldest companions – the trees.

1. Eligibility Requirements

1.1 Project Operators

A Project requires at least one Project Operator ("PO"), an individual or an entity, who undertakes a Project, registers it with the Urban Forest Carbon Registry (the "Registry"), and is ultimately responsible for all aspects of the project and its reporting.

1.2 Project Implementation Agreement

A Project Operator must sign a Project Implementation Agreement (PIA) with the Registry setting forth the Project Operator's obligation to comply with this Protocol.

1.3 Project Location

Projects must be located within at least one of the following:

A. The Urban Area boundary ("Urban Area"), defined by the most recent publication of the United States Census Bureau (https://www.census.gov/geo/maps-data/maps/2010ua.html);

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. A zone or area designated by any governmental entity as a watershed or for source water protection, provided the designated zone or area overlaps some portion of A, B, or C above;

E. A transportation, power transmission, or utility right of way, provided the right of way begins, ends, or passes through some portion of A, B, C, or D above.

1.4 Ownership or Eligibility to Receive Potential Credits

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

A. Own the land 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 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 for the Project Duration of any credits for carbon storage or other benefits delivered by Project trees on that landowner's land.

2. Project Duration

[The Registry is working to establish a 40-year buffer (reserve) pool of additional forest carbon to collateralize or insure the urban carbon stored in Project trees. Details to come.]

Projects must submit Project Reports (at intervals of their choice) to the Registry for 25 years from commencement ("Project Duration"). Projects may earn credits after the 25-year Project Duration as provided in Section 8.

Projects can shorten the Project Duration requirement only if the project converts project trees to wood products (and seek credits only until that conversion). **[Details under development]**

3. Project Documentation, Reporting, and Record-keeping

Documentation, reporting, and record-keeping requirements are contained in Appendix A. All projects must quantify carbon stored and submit a Project Report at the end of the 25-year Project Duration. Projects may seeks credits earlier under Section 6.

4. Project Commencement

A Project commences when the Project Operator submits an application, provided the Registry approves that application within six months of submittal.

5. Legally Required Trees on Private Property Not Eligible

Trees planted on private property due to an enacted ordinance or law are not eligible.

6. Issuance of Credits for Tree Planting Projects

The Registry will issue Community Carbon Credits, representing a metric tonne of carbon, bundled with quantified co-benefits such as storm water interception and cooling.

The Registry will issue credits to projects that comply with the requirements of this protocol, as follows:

6.1 Progress Credits

A Project Operator can choose to quantify carbon stored at any time after Year 5 of a tree-planting project and to request verification and issuance of credits by the Registry.

After an issuance of Progress Credits, the credit amount issued shall be the change in carbon stored from the prior issuance of credits.

6.2 Forward Credits

[The Registry is working to establish a 40-year buffer (reserve) pool of additional forest carbon to collateralize or insure the urban carbon stored in Project trees. Details to come.]

If a Project Operator chooses not to request Progress Credits, the Registry will issue forward credits on the following tiered schedule:

A. After planting of project trees: 10% of projected total carbon stored by Year 26;

B. After Year 3: 40% of projected total carbon stored by Year 26;

C. After year 5: 30% of projected total carbon stored by Year 26;

D. At the end of the 25-year Project Duration and after quantification and verification of carbon stored: "true-up" credits equaling the difference between credits already issued (which were based on projected carbon stored) and credits earned based on quantified and verified carbon stored;

E. 5% of total credits earned will be retained by the Registry at the last issuance of credits to a Project for use in a Registry-wide a Reversal Pool;

Projects can continue after Year 25, and earn credits, as provided in Section 8.

7. Reversals in Tree Planting Projects

All Project Operators must sign a Project Implementation Agreement with the Registry. This Agreement may obligate Project Operators in certain defined circumstances to do the following, among other things: 1) agree to a hold-back or retainage of credits until the expiration of the 25-year Project Duration, upon which the retained credits would be released, or 2) return to the Registry for cancellation credits that have been issued for project trees that are lost and/or 2) forgo future credits in the same amount as those that should have been returned, and/or 3) contribute to a Reversal Pool of credits.

7.1 Reversals in Projects Receiving Progress Credits

A. Tree planting projects that seek Progress Credits shall not quantify carbon stored or request issuance of credits in the first five years of a tree-planting project, when most mortality occurs.

B. A reversal in a project receiving Progress Credits is any decline in carbon stored between the following two points in time:

i. receipt by the project of credits for stored carbon and

ii. final quantification of carbon stored at the end of the project's 25-year Project Duration.

C. If a project shows a decline in carbon stored in subsection 7.1B above, it must return credits equal to the amount of the decline ("Unearned Progress Credits") and forgo issuance of current and future credits until the Unearned Progress Credits are made up.

D. If a Project Operator fails to compensate for Unearned Progress Credits as above, that Operator may be barred from urban forest carbon projects for a specified time period at the discretion of the Registry.

7.2 Reversals in Projects Receiving Forward Credits

A. At the final quantification and true-up of credits at the end of the 25-year Project Duration, the Registry will retain 5% of total credits earned.

B. If a project has received more forward credits than it has earned based on the final quantification and true-up ("Unearned Forward Credits"), it must return credits equal to the amount of those Unearned Forward Credits received and/or forgo issuance of current and future credits until the Unearned Forward Credits are made up.

C. If a Project Operator fails to compensate for a reversal, that Operator may be barred from urban forest projects for a specified time period at the discretion of the Urban Forest Carbon Registry.

8. Continuation of Tree Planting Projects after 25-Year Project Duration

After the minimum 25-year Project Duration, projects may continue their activities, submit Project Reports under Appendix A, and seek issuance of credits under Section 6. Projects must comply with all applicable requirements of this Protocol.

If a project chooses to continue into a Second Project Duration, it can:

A. seek Progress Credits as provided in subsection 6.1, but without the five-year waiting period in that subsection, or

B. seek Forward Credits as provided in subsection 6.2 for its Second Project Duration by re-setting its 25-year Project Duration. During this Second Project Duration, it need not request issuance of credits on the tiered schedule in that subsection, but may request Forward Credits at any time equal to 80% of projected total carbon stored. The remaining 20% of credits shall be accounted for as provided in subsections 6.2 D and E.

9. Quantification of Carbon and Co-Benefits for Credits

The Registry will issue Community Carbon Credits to a Project upon request by a Project Operator and verification of compliance with this Protocol. Project Operators must follow the Quantification methods set forth in Appendix B.

Appendix B sets out two methods for quantification, one for single trees and one for tree canopy. Each method requires certain steps, data samples from the Project Operator, data from look-up tables that are or will be provided, and calculations.

Appendix B also provides methods for calculating co-benefits, such as storm water interception, air quality, and energy savings. And Appendix B sets out a method for projecting carbon storage for Tree Planting projects seeking Forward Credits.

10. Verification

The Registry will issue credits only after a Project Operator submits a Project Report and undergoes verification by the Registry. Credits issued prior to completion of the 25-year project period will be subject to the Reversal Requirements set forth in Section 7.

The Registry will verify compliance with this Protocol per ISO 14064-3 as set forth below and in App. C.

Appendix C sets out verification methods and standards. Here is a summary.

- Verification will be conducted by a verification official at the Registry, with review by a peer reviewer.

- App. C sets out standards for verification, including thoroughness, accuracy, sampling, and other elements, for both the Single Tree Method and the Tree Canopy Method, and for the issuance of Forward Credits. App. C will also contain standards for geocoded photographs, data, or similar landmarking that provides verification of the Project Operator's data on quantification.

- For the Single Tree Method, the Project Operator will provide geocoded photographs with species and DBH (diameter at breast height) for a sample of project trees. The Registry verification official will then confirm that the photographed species and DBH match the data submitted as "recorded in the field" and are consistent with data from the original Project Plan.

- For the Tree Canopy Method, the Project operator will submit to the Registry the i-Tree Canopy file that they developed, including locations used to calculate canopy area. The Registry verification official will use a subsample of these points to independently estimate canopy area for the same project area.

- For projects requesting forward credits on the tiered release in Section 2.3.B, the Project Operator will send to the Registry geocoded photographs of a sampling of project trees or canopy, or provide maps or images from Google Earth or other accepted imaging standards that allow verification of project trees.

- Project Operators may use data from management or maintenance activities regularly conducted if the data was collected within 12 months of the project's request for credits.

Appendix A

Project Documentation, Reporting, and Record-keeping for Tree Planting and Tree Preservation Projects

A.1 Documentation to Submit a Project

Project Operators must provide the following documentation to submit their project to the Registry.

Document	When Submitted	Content Summary
Project Submittal Form	Once, at or within one year of Project Commencement	Project Operator, Location, Summary of Project
Project Plan	Once, with Project Submittal Form or within one year of Project Commencement	Design of Project, Compliance with Eligibility Requirements, Data on Trees for Projections and Quantification per Section ___.
Project Implementation Agreement with the Registry	Once, within one year of Project Commencement	Agreement Binding the Project Operator, specific provisions to come
Signed Affidavit of Land Ownership or Permission per Section ___.	With Project Implementation Agreement, or upon any change in ownership or permission	Affidavit of Project Operator on Ownership of Land or Permission
Signed Affidavit of Compliance	With Project Implementation Agreement	Affidavit of PO on compliance with requirements of protocol

A.2 Documentation for Quantification, Verification, and Request for Issuance of Credits

Project Operators must submit the following documentation on status and to request verification and issuance of credits by the Registry.

Document	When Submitted/Required	Content Summary
Status Reports	Annually, at anniversary of project commencement	One-page report to be filled in confirming Project Operator, operational status, and any significant variations from Project Plan
Project Reports, including quantification of carbon	Always at end of 25-year Project Duration. Before that, at Project Operator's discretion, but required before verification or issuance of credits.	Status of Project, Update on Eligibility, project trees for Forward Credits, quantification, and comparison of projected carbon storage with quantified carbon if received Forward Credits.

A.3 Reporting During and at End of Project Duration

A Project Report must be submitted at the end of a project's 25-year Project Duration. During the 25-year span of a project, the Project Operator may submit a Project Report and seek verification and issuance of credits at any interval chosen by the Project Operator. The Registry will not verify or issue credits without a Project Report.

Project Reports must contain:

a. Any updated information or data on eligibility, and

b. Updated project inventories, data on existence of project trees for issuance of Forward Credits, and any quantification data required by Section 9 and Appendices B or C on quantification and verification.

A.4 Record Keeping

Project Operators shall keep all documents and forms related to the project for a minimum of the 25-year Project Duration. If the Project seeks credits after the 25-year Project Duration, it must retain all documents for as long as it seeks issuance of credits. This information may be requested by the Registry at any time.

A.5 Transparency

The Registry requires data transparency for all Projects, including data that displays current carbon stocks, reversals, and quantification of carbon stored. For this reason, all project data reported to the Registry will be publicly available on the Registry's website or by request.

Appendix B

Quantification Methods

This Appendix B on Quantification consists of a Summary of Quantification Steps, followed by a longer section entitled Quantification Methods and Examples, which provides a more detailed walk-though of quantification methods using a sample project.

Summary of Quantification Steps

This section summarizes the steps to quantify carbon storage in tree planting projects. Two different methods are available. Project Operators can select to use the Single Tree Method (where planted trees are scattered among many existing trees, such as street or yard tree plantings) or the Tree Canopy Method (where planted trees are relatively contiguous, such as in park or riparian plantings).

The Single Tree Method requires tracking and sampling of individual trees. The Tree Canopy Method requires tracking of changes in the project's overall tree canopy area. Steps for quantification are presented for Forward Crediting and for use at any time after planting. Appendix B also contains an example for each method, with associated spreadsheet tables and calculations.

Steps for the Single Tree Method

1) Describe the project (i.e., dates trees planted, general locations and climate zone used for calculations).
2) Create a planting list that contains data on the numbers of trees planted by species (with tree-type for each species), location and date. We provide tables for each climate zone that match species with tree-types.
3) Use the Sample Size Calculator that we provide and the Stored CO_2 per Tree Look-Up Table to determine the number of tree sites to sample. We define a "tree site" as the location where a project tree was planted, and use the term "site" instead of "tree" because some planted trees may no longer be present in the sites where they were planted.
4) Randomly sample tree sites collecting data on species, status (alive, dead, removed, replaced), dbh (to nearest inch) and photo of tree site (may be with or without the tree planted) with geocoded location and date.

5) Fill-in the table provided showing the number of live trees sampled in each 1” dbh class by tree-type.
6) Combine data from the step 5 table with the CO_2 Stored by DBH Look-Up Table for your climate zone to calculate CO_2 stored by sampled trees for each tree-type.
7) Fill-in the table provided showing number of sites planted, sites sampled and status of sampled tree sites by tree-type. This table calculates Extrapolation Factors.
8) Combine data from tables in step 7 (Extrapolation Factors) and step 6 to scale-up CO_2 stored from the sample to the population of trees planted.
9) Fill-in the table provided to incorporate error estimates of ±15% to CO_2 stored by the entire tree population.
10) Fill-in the table provided to incorporate estimates of co-benefits.

Forward Crediting – Single Tree Method

1) Fill-in the table provided using data from the Stored CO_2 per Tree Look-Up Table for 25 years after planting and number of trees planted by tree-type. It will apply the 10% deduction to account for likely tree losses and the percentages of credits issued at years 1 (10%), 3 (40%) and 5 (30%) after planting.

Steps for the Tree Canopy Method

1) Describe the project (i.e., dates trees planted, locations and climate zone).
2) Create a planting list that contains data on the numbers of trees planted by species (with tree-type for each species obtained from the table provided).
3) Fill-in the table provided using data from the Stored CO_2 per Unit Canopy Look-Up Table for 25 years after planting and numbers of trees planted by tree-type to calculate the Project Index.
4) Use i-Tree Canopy to calculate total project area and area in tree canopy.
5) In the table provided, multiply the area in tree canopy by the Project Index to calculate total CO_2 stored by trees planted in the project area.
6) Fill-in the table provided to incorporate error estimates of ±15% to CO_2 stored by the entire tree population.
7) Fill-in the table provided to incorporate estimates of co-benefits.

Forward Crediting – Tree Canopy Method

1) Fill-in the table provided using data from the Stored CO_2 per Unit Canopy Look-Up Table for 25 years after planting and the No Loss Tree Canopy value. The No Loss Tree Canopy value is the product of the 25-yr UTC per tree and the number of trees planted by tree-type. The table will automatically apply the 10% deduction to account for likely tree losses and the percentages of credits issued at years 1 (10%), 3 (40%) and 5 (30%) after planting.

Quantification Methods and Examples

There are two different methods for quantifying carbon storage in urban forest carbon projects – the Single Tree Method (where planted trees are few or are scattered among many existing trees) and the Tree Canopy Method (where planted trees are relatively contiguous). The Project Operator (PO) can decide which approach to use.

This Appendix shows steps for quantification of carbon dioxide (CO_2) stored and for co-benefits for hypothetical projects. Also, it illustrates how to use the two methods to forecast carbon storage for the issuance of forward credits.

Single Tree Method
The PO calculates the amount of CO_2 currently stored by planted project trees in metric tonnes (t) on a tree-by-tree basis and calculates the total for all live trees, based on sampling of the resource. The following steps are required and illustrated for a hypothetical planting of 500 street/front yard sites in Sacramento, with 71 trees sampled 25-years after planting.

Step 1. Acquire the following information: numbers of trees planted, date planted, species name and tree-type for each species, gps location and climate zone (Table 1). Tree types: BDL = broadleaf deciduous large, BDM = broadleaf deciduous medium, BDS = broadleaf deciduous small, BEL = broadleaf evergreen large, BEM = broadleaf evergreen medium, BES = broadleaf evergreen small, CEL = conifer evergreen large, CEM = conifer evergreen medium, CES = conifer evergreen small.

Table 1. Planting list for street tree sites in Sacramento, CA (Inland Valley climate zone).

Planting List (Species)	Common Name	Tree-Type	Number Planted	Tree-Type Subtotals
Celtis australis	European hackberry	BDL	45	
Quercus lobata	valley oak	BDL	40	
Ulmus species	elm	BDL	35	120
Jacaranda mimosifolia	jacaranda	BDM	40	
Melia azedarach	Chinaberry	BDM	30	70
Chitalpa tashkentensis	chitalpa	BDS	30	
Diospyros kaki	Japanese persimmon	BDS	20	50
Grevillea robusta	silk oak	BEL	45	
Quercus suber	cork oak	BEL	35	80
Acacia species	acacia	BEM	30	
Eucalyptus cinerea	silver dollar eucalyptus	BEM	25	55
Laurus nobilis	laurel de olor	BES	30	30
Cedrus atlantica	Atlas cedar	CEL	25	
Pinus halepensis	aleppo pine	CEL	25	50
Pinus pinea	Itailian stone pine	CEM	20	
Juniperus species	juniper	CEM	25	45
Total Sites Planted			500	500

Step 2. Measure and record species, status (i.e., alive, standing dead, removed (date), replaced (date/species) and current dbh of live trees (to nearest 1-inch or 2.54-cm) from a sample or census of planted tree sites.

The number of tree sites to sample is derived using the Sample Size Calculator (Fig. 1).

Figure 1. The PO enters project information described below to calculate the sample size necessary to adequately quantify carbon storage.

	Sample Size Calculator*	
Description		**Value**
1) Choose:	**Margin of Error (15% recommended)**	**15%**
2) Choose:	**Confidence level (95% recommended)**	**95%**
3) Enter:	**Total number of project sites**	**500**
4) Enter:	**Mean stored CO2 per tree (kg)**	**1,534**
5) Enter:	**Standard deviation of stored CO2 (kg)**	**832**
6) Enter:	**Expected proportion of tree survival**	**85%**
	Calculated sample size	**76**

* Normally assumes 15% margin of error at a 95% confidence interval.

The PO enters the following information:

1) Choose the margin of error from the drop down menu, 15% is recommended.
2) Choose the confidence level value (%) from the drop down menu, 95% is recommended.
3) The total number of sites - Enter the total number of original sites, in this example 500.
4) Mean stored CO_2 per tree – using Table 2, look-up the mean CO_2 stored by all tree types for the closest age after planting date, in this case 25-years after planting. Enter this number (1,534 kg) into the Sample Size Calculator.
5) Standard deviation of stored CO_2 – using Table 2, look-up the standard deviation of CO_2 stored by all tree types for the closest age after planting date, in this case 25-years after planting. Enter this number (832 kg) into the Sample Size Calculator.
6) Expected proportion of tree survival – estimates of survival rates can be based on project experience or pre-sampling. Enter the proportion (%) of expected tree survival into the Sample Size Calculator, in this case 85% (this can be calculated by dividing the expected or known number of trees that have survived by the total number of trees that were planted and then multiplying by 100). Note: if you do not have an estimate for tree survival, 50% should be entered.

Table 2. The Stored CO_2 By Age Look-Up Table shows kg stored per tree by tree-type for years after planting in Sacramento, CA (Inland Valley climate zone). There is an equivalent table for each of the 16 U.S. climate zones. Values in the highlighted column for 25-year old trees are used in the Sample Size Calculator and Forward Crediting.

CO2 (kg)	BDL	BDM	BDS	BEL	BEM	BES	CEL	CEM	CES		Std.
Age	ZESE	PYCA	PRCE	CICA	MAGR	ILOP	SESE	PIBR2	PICO5	Avg.	Dev.
5	45	251	78	59	24	13	39	13	47		
10	236	725	230	239	133	60	259	203	167		
15	630	1,232	395	570	315	150	761	964	315		
20	1,256	1,735	560	1,062	550	288	1,623	2,021	475		
25	2,127	2,223	721	1,718	824	478	2,912	2,162	640	1,534	832
30	3,243	2,695	877	2,536	1,128	725	4,688	2,265	807		
35	4,595	3,150	1,028	3,505	1,454	1,031	7,006	2,371	974		
40	6,166	3,589	1,174	4,614	1,799	1,400	9,918	2,479	974		

In this example, 76 sites are needed for sampling to achieve a 15% margin of error with a 95% confidence level for the 500 original project sites, 25 years after planting. Because the gps location of each site was taken when the trees were planted, relocating the tree sites is straightforward. The PO randomly samples 76 of the original sites without bias, visiting each site whether a tree is known to be alive, dead or removed. Because each site is numbered she creates a random number list (i.e., RANDBETWEEN function) without duplicates in Excel to identify the sites to sample.

Table 3. Results from Step 2 combined with information from Step 1 indicate that 76 sites were sampled, 19 of the originally planted trees were removed and 57 remained alive (57+19=76). Of the 19 trees that were removed, 17 were replaced with the same tree-type. Hence, the total number of live trees is 74 (57 originals +17 replacements). This example assumes that all replacements survived.

Sample Data	Tree-Type	No. Sites Planted	No. Sites Sampled	No. Removed Trees	No. Live Trees	No. Replaced Trees	Total Live + Replaced Trees
Brdlf Decid Large (>50 ft)	BDL	120	20	4	15	4	19
Brdlf Decid Med (30-50 ft)	BDM	70	10	3	7	3	10
Brdlf Decid Small (<30 ft)	BDS	50	9	3	7	2	9
Brdlf Evgrn Large (>50 ft)	BEL	80	12	2	9	2	11
Brdlf Evgrn Med (30-50 ft)	BEM	55	7	3	4	3	7
Brdlf Evgrn Small (<30 ft)	BES	30	4	1	3	1	4
Conif Evgrn Large (>50 ft)	CEL	50	8	1	7	1	8
Conif Evgrn Med (30-50 ft)	CEM	45	6	2	5	1	6
Conif Evgrn Small (<30 ft)	CES	0	0	0	0	0	0
		500	76	19	57	17	74

Step 3. Record the number of live + replaced trees sampled by tree-type and dbh class (Table 4).

Table 4. This table shows the distribution of the 74 live sampled trees by dbh class. Replacement trees are smaller than the originally planted trees. The initial version of this table is in 1-inch dbh increments, because tree dbh is measured to the nearest 1-inch. The spreadsheet will bin these into 3- and 6-inch dbh classes used to calculate co-benefits.

	Tree-Type	0-3"	3-6"	6-9"	9-12"	12-15"	15-18"	18-21"	21-24"	24-27"	27-30"	Total Number
Brdlf Decid Large (>50 ft)	BDL	2	2	1	4	5	5	0	0	0	0	19
Brdlf Decid Med (30-50 ft)	BDM	3	0	0	0	2	5	0	0	0	0	10
Brdlf Decid Small (<30 ft)	BDS	0	2	2	5	0	0	0	0	0	0	9
Brdlf Evgrn Large (>50 ft)	BEL	1	1	1	0	0	4	4	0	0	0	11
Brdlf Evgrn Med (30-50 ft)	BEM	2	1	0	0	2	2	0	0	0	0	7
Brdlf Evgrn Small (<30 ft)	BES	1	0	1	2	0	0	0	0	0	0	4
Conif Evgrn Large (>50 ft)	CEL	0	1	0	0	0	0	0	0	6	1	8
Conif Evgrn Med (30-50 ft)	CEM	1	0	0	0	0	0	3	2	0	0	6
Conif Evgrn Small (<30 ft)	CES	0	0	0	0	0	0	0	0	0	0	0
		10	7	5	11	9	16	7	2	6	1	74

Step 4. Multiply the number of live trees for each tree-type in Table 4 by the CO_2 Stored by DBH Look-Up Table values in Table 5 below. The amount of CO_2 stored is calculated and shown for sampled live trees in Table 6 below.

Table 5. CO_2 Stored by DBH Look-Up Table. The version of the table shows values in 1-inch dbh increments. There is a separate table for each of the 16 US climate zones.

dbh (cm)	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9	25.4	27.9	30.5	33.0	35.6	38.1	40.6	43.2	45.7	48.3	50.8	53.3	55.9	58.4	61.0	63.5	66.0	68.6	71.1	73.7	76.2
dbh (inches)	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"	12"	13"	14"	15"	16"	17"	18"	19"	20"	21"	22"	23"	24"	25"	26"	27"	28"	29"	30"
Brdlf Decid Large (>50 ft)	1	5	14	30	55	89	135	193	265	351	453	571	708	863	1,038	1,233	1,451	1,690	1,953	2,240	2,553	2,891	3,256	3,649	4,069	4,520	5,000	5,510	6,053	6,627
Brdlf Decid Med (30-50 ft)	3	17	44	85	142	216	309	420	552	704	878	1,073	1,291	1,532	1,797	2,086	2,399	2,738	3,103	3,493	3,910	4,354	4,824	5,323	5,850	6,404	6,988	7,601	8,243	8,914
Brdlf Decid Small (<30 ft)	3	13	34	66	111	169	242	329	432	552	687	840	1,011	1,200	1,408	1,634	1,880	2,145	2,430	2,736	3,063	3,410	3,779	4,170	4,582	5,017	5,474	5,954	6,457	6,983
Brdlf Evgrn Large (>50 ft)	1	6	18	37	64	102	151	212	285	373	475	592	725	875	1,042	1,227	1,431	1,654	1,896	2,160	2,444	2,750	3,078	3,428	3,802	4,200	4,621	5,067	5,539	6,036
Brdlf Evgrn Med (30-50 ft)	1	4	12	26	47	76	114	162	221	291	374	470	580	704	844	999	1,172	1,361	1,568	1,794	2,039	2,303	2,588	2,894	3,220	3,569	3,941	4,335	4,753	5,194
Brdlf Evgrn Small (<30 ft)	3	14	37	71	119	182	260	355	466	594	741	906	1,091	1,295	1,519	1,764	2,030	2,317	2,626	2,956	3,310	3,686	4,086	4,509	4,955	5,426	5,922	6,442	6,987	7,557
Conif Evgrn Large (>50 ft)	1	4	11	23	41	66	98	139	188	247	316	395	486	588	703	830	970	1,124	1,292	1,475	1,673	1,886	2,115	2,360	2,622	2,901	3,197	3,511	3,844	4,195
Conif Evgrn Med (30-50 ft)	1	5	13	28	49	79	118	166	225	295	377	472	580	702	839	991	1,159	1,343	1,543	1,762	1,998	2,252	2,526	2,819	3,132	3,465	3,819	4,194	4,591	5,011
Conif Evgrn Small (<30 ft)	1	4	12	25	44	70	104	147	199	261	333	417	513	621	742	876	1,024	1,187	1,364	1,557	1,766	1,990	2,232	2,491	2,767	3,062	3,375	3,707	4,058	4,428

Table 6. CO_2 stored for the 74 sampled live trees (kg) (rounded to the nearest whole number)

dbh (cm)	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9	25.4	27.9	30.5	33.0	35.6	38.1	40.6	43.2	45.7	48.3	50.8	53.3	55.9	58.4	61.0	63.5	66.0	68.6	71.1	73.7	76.2	Sample
dbh (inches)	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"	12"	13"	14"	15"	16"	17"	18"	19"	20"	21"	22"	23"	24"	25"	26"	27"	28"	29"	30"	Total
Brdlf Decid Large (>50 ft)	0	5	14	0	110	0	0	0	265	351	905	571	1,416	1,726	1,038	1,233	2,901	3,380	0	0	0	0	0	0	0	0	0	0	0	0	13,915
Brdlf Decid Med (30-50 ft)	3	17	44	0	0	0	0	0	0	0	0	0	1,291	0	1,797	4,172	2,399	5,476	0	0	0	0	0	0	0	0	0	0	0	0	15,199
Brdlf Decid Small (<30 ft)	0	0	0	66	111	0	0	0	865	1,655	1,375	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,072
Brdlf Evgrn Large (>50 ft)	0	6	0	0	64	0	0	212	0	0	0	0	0	0	0	1,227	2,861	1,654	3,793	4,319	0	0	0	0	0	0	0	0	0	0	14,136
Brdlf Evgrn Med (30-50 ft)	0	0	25	26	0	0	0	0	0	0	0	0	0	704	844	999	1,172	0	0	0	0	0	0	0	0	0	0	0	0	0	3,770
Brdlf Evgrn Small (<30 ft)	0	14	0	0	0	0	0	355	0	594	741	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,704
Conif Evgrn Large (>50 ft)	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,622	8,702	6,394	3,511	0	0	21,253
Conif Evgrn Med (30-50 ft)	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,543	1,762	1,998	2,252	2,526	0	0	0	0	0	0	0	10,095
Conif Evgrn Small (<30 ft)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	42	96	116	285	0	0	566	1,129	2,600	3,021	571	2,707	2,430	3,678	7,631	9,333	10,510	5,336	6,081	1,998	2,252	2,526	0	2,622	8,702	6,394	3,511	0	0	84,145

Step 5. In this step Extrapolation Factors are calculated that are used to scale-up tree numbers from the sample to the population. Calculate the Extrapolation Factor (# sites planted / # sites sampled) for each tree-type (Table 7). Although not required for the carbon calculations, the sample's gross and net survival rates show the significance of replacement plantings. Gross survival is calculated without replacement as:

Gross survival = (# live that were originally planted/#sample sites)*100

Net survival is with replacements = (total live+replaced / #sample sites)*100

Table 7. Of the original planting, sample results indicate that 75% survived (i.e., gross survival rate). With replacements, 97.4% of the sites contained live trees (i.e., net survival rate). The Extrapolation Factor for each tree-type is shown (i.e., for the CEM tree-type it is 7.5 (45/6).

Sample Data	Tree-Type	Number Sites Planted	No. Sites Sampled	No. Live (Original Planting)	Gross Survival (%)	No. Replace-ment Plt.	Total Live + Replaced Trees	Net Survival (%)	Extrap. Factor
Brdlf Decid Large (>50 ft)	BDL	120	20	15	75.0	4	19	95.0	6.00
Brdlf Decid Med (30-50 ft)	BDM	70	10	7	70.0	3	10	100.0	7.00
Brdlf Decid Small (<30 ft)	BDS	50	9	7	77.8	2	9	100.0	5.56
Brdlf Evgrn Large (>50 ft)	BEL	80	12	9	75.0	2	11	91.7	6.67
Brdlf Evgrn Med (30-50 ft)	BEM	55	7	4	57.1	3	7	100.0	7.86
Brdlf Evgrn Small (<30 ft)	BES	30	4	3	75.0	1	4	100.0	7.50
Conif Evgrn Large (>50 ft)	CEL	50	8	7	87.5	1	8	100.0	6.25
Conif Evgrn Med (30-50 ft)	CEM	45	6	5	83.3	1	6	100.0	7.50
Conif Evgrn Small (<30 ft)	CES	0	0	0	0.0	0	0	0.0	0.00
		500	76	57	75.0	17	74	97.4	

Step 6. Apply the Extrapolation Factors from Table 7 to scale-up from the sample to the population for each tree-type (Extrap. Factor * Live Sample Trees = Total Number of Live Trees). Cut and paste the Sample CO_2 Total (kg) from Table 6, and multiply by the Total Number of Live Trees to calculate Grand Total CO_2. Convert from kg to metric tonnes (divide by 1000) (Table 8).

Table 8. This table shows that there are an estimated 487 live trees (Ext. Factors x Live Sample Trees). The amount of CO_2 stored by the 76 sample trees is 84,145 kg, and when converted to tonnes and extrapolated to the population of 487 trees, totals 557.7 t CO_2.

Sample Data	Tree-Type	No. Sites Planted	Extrap. Factor	Live Sample Trees	Total Number Live Trees	Sample CO2 Tot. (kg)	Grand Total CO2 (t)
Brdlf Decid Large (>50 ft)	BDL	120	6.00	19	114	13,915	83.5
Brdlf Decid Med (30-50 ft)	BDM	70	7.00	10	70	15,199	106.4
Brdlf Decid Small (<30 ft)	BDS	50	5.56	9	50	4,072	22.6
Brdlf Evgrn Large (>50 ft)	BEL	80	6.67	11	73	14,136	94.2
Brdlf Evgrn Med (30-50 ft)	BEM	55	7.86	7	55	3,770	29.6
Brdlf Evgrn Small (<30 ft)	BES	30	7.50	4	30	1,704	12.8
Conif Evgrn Large (>50 ft)	CEL	50	6.25	8	50	21,253	132.8
Conif Evgrn Med (30-50 ft)	CEM	45	7.50	6	45	10,095	75.7
Conif Evgrn Small (<30 ft)	CES	0	0.00	0	0	0	0.0
		500		74	487	84,145	557.7

Step 7. Incorporate error estimates and prices to illustrate the range of amount stored and value (Table 9). Sum the tonnes of CO_2 for the three tree-types (Brdlf Decid, Brdlf Evgrn, and Conif Evgrn) and put the totals into Table 9.

Table 9. This summary table shows that with the ±15% error added to the 557.7 t grand total CO_2 stored (see Appendix 1), the actual amount of CO_2 stored is likely to range between 474 t and 641 t. The estimated value, assuming prices of $20 and $40 per tonne, ranges from $9,481 to $25,654.

	t CO2	$ 20.00	$ 40.00
Tree-Type	at 25 yrs	$ value	$ value
Brdlf Decid	212.5	$ 4,250	$ 8,500
Brdlf Evgrn	136.6	$ 2,733	$ 5,466
Conif Evgrn	208.5	$ 4,171	$ 8,342
Total	557.7	$ 11,154	$ 22,308
	CO2 (t)	Total $	Total $
Total CO2 (t):	557.7	$ 11,154	$ 22,308
High Est.:	641.3	$ 12,827	$ 25,654
Low Est.:	474.0	$ 9,481	$ 18,962
± 15% error = ± 10% formulaic ± 3% sampling			
± 2% measurement (see Appendix 1)			

Step 8. Calculate co-benefits (Table 10).

Co-benefits are shown in Table 10 for 487 live trees 25-years after planting. The total annual value of ecosystem services is $13,861, or $27.72 per site (500 tree sites planted). Estimated energy savings ($6,807) are primarily associated with reductions in air conditioning use due to tree shading and climate effects. Rainfall interception and associated stormwater management savings have an estimated value of $3,291. Benefits associated with the uptake of air pollutants by trees (net $3,278) is somewhat offset by BVOC emissions. Avoided CO_2 emissions associated with energy savings is valued at $486 assuming a CO_2 price of $20 per t. These co-benefits are first-order approximations and dollar values may not reflect the most current prices for local environmental and utility services.

Table 10. Co-benefits estimated for the 487 live trees 25 years after planting calculated using the Inland Valley data found in the i-Tree Streets and Design software. i-Tree prices were used, except for CO_2 , which was $20 per tonne.

Resource Units in ( )		Res Units	RU/site	Total $	$/site
Interception (m3)		1,597.0	3.19	$3,291	$6.58
CO2 Avoided (kg, $20/t)		24,289	48.58	$486	$0.97
Air Quality (kg)					
O3		135.35	0.27	$1,493	$2.99
NOx		36.39	0.07	$1,026	$2.05
PM10		86.04	0.17	$1,785	$3.57
Net VOCs		-99.27	-0.20	-$1,026	-$2.05
Air Quality Total		158.52	0.32	$3,278	$6.56
Energy (kWh & kBtu)					
Cooling - Elec.		56,987	113.97	$6,645	$13.29
Heating - Nat. Gas		13,009	26.02	$162	$0.32
Energy Total				$6,807	$13.61
Grand Total				$13,861	$27.72

Forward Crediting – Single Tree Method (Table 11)

This example (Table 11) assumes that the Registry issues forward credits in the amounts of 10%, 40% and 30% at Years 1, 3 and 5 after planting, respectively, of the forecasted CO_2 stored by project trees 25-years after planting. In the example, we deduct 10% of the Stored CO_2 at 25-years after planting to account for likely tree losses. We assume a price of $20 per tonne. The Total 25-year CO_2 Stored value (i.e., grand total of 798.2 t CO_2) was calculated as the product of 90% of the 25-year CO_2 Stored (kg/tree) values from Table 2 and the number of live trees.

Table 11. Forecasted forwarded CO_2 credits based on a 10% deduction from the amount stored 25-years after planting and value assuming $20/t.

	No. Trees	stored (kg/tree)	Tot. 25-yr CO2 stored (t)	10% CO2 (t)	40% CO2 (t)	30% CO2 (t)	10% CO2 ($)	40% CO2 ($)	30% CO2 ($)
BDL	120	2,127	229.7	23.0	91.9	68.9	$ 459	$ 1,838	$ 1,378
BDM	70	2,223	140.1	14.0	56.0	42.0	$ 280	$ 1,120	$ 840
BDS	50	721	32.4	3.2	13.0	9.7	$ 65	$ 259	$ 195
BEL	80	1,718	123.7	12.4	49.5	37.1	$ 247	$ 990	$ 742
BEM	55	824	40.8	4.1	16.3	12.2	$ 82	$ 326	$ 245
BES	30	478	12.9	1.3	5.2	3.9	$ 26	$ 103	$ 77
CEL	50	2,912	131.0	13.1	52.4	39.3	$ 262	$ 1,048	$ 786
CEM	45	2,162	87.6	8.8	35.0	26.3	$ 175	$ 701	$ 525
CES	0	640	0.0	0.0	0.0	0.0	$0	$0	$0
	500		798.2	79.8	319.3	239.5	$ 1,596	$ 6,386	$ 4,789

Tree Canopy Method

The PO estimates the amount of CO_2 currently stored by planted project trees in metric tonnes (t) based on the amount of tree canopy (TC) determined from remote sensing and an index (CO_2 per unit canopy area) that is weighted by the mix of species planted. The following steps are illustrated for a hypothetical planting of 500 tree sites along a creek in Sacramento, CA measured 25-years after planting.

Step 1. Describe the project, quantify the project area, acquire the following information: numbers of trees planted, date planted, species name and tree-type for each species, gps locations and climate zone (Table 1).

The 500 trees were planted 25-years ago along the Bannon Creek Parkway bordered by Azevedo Dr. (west), Bannon Creek Elementary School (north and east) and West El Camino Ave. (south) (Figure 1). The Project Area, shown outlined in red using a Google image in the i-Tree Canopy application, covers 12.5 acres (5.1 ha). The numbers of trees originally planted are shown by species and tree-type in Table 1.

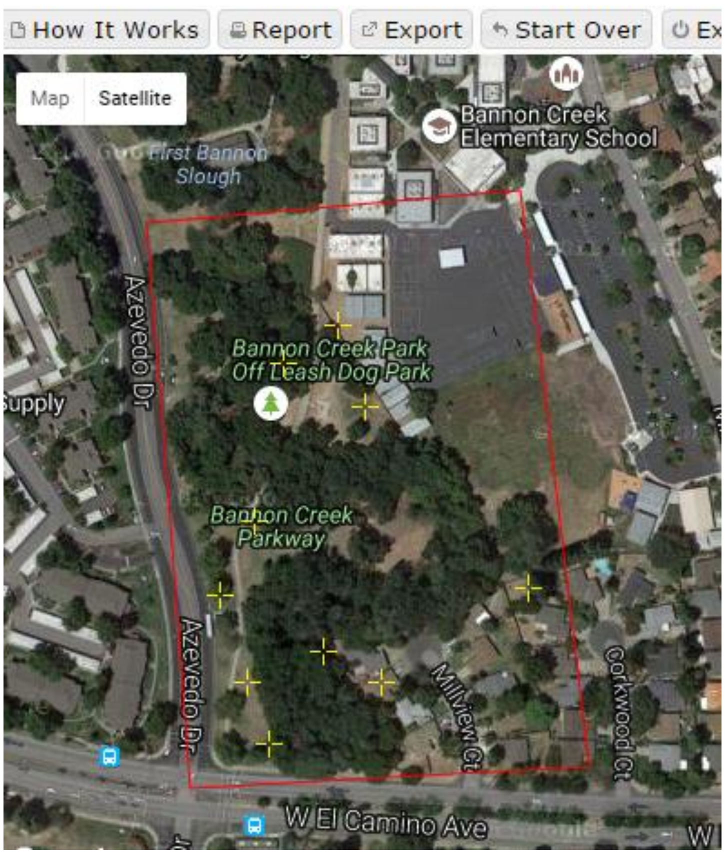

Figure 1. The Project Area where 500 trees were planted 25-years ago in Sacramento, CA.

Table 1. Planting list for trees planted 25-years ago in the Bannon Creek Parkway Project Area, Sacramento, CA (Inland Valley climate zone)

Planting List (Species)	Common Name	Tree-Type	Number Planted	Tree-Type Subtotals
Celtis australis	European hackberry	BDL	45	
Quercus lobata	valley oak	BDL	40	
Ulmus species	elm	BDL	35	120
Jacaranda mimosifolia	jacaranda	BDM	40	
Melia azedarach	Chinaberry	BDM	30	70
Chitalpa tashkentensis	chitalpa	BDS	30	
Diospyros kaki	Japanese persimmon	BDS	20	50
Grevillea robusta	silk oak	BEL	45	
Quercus suber	cork oak	BEL	35	80
Acacia species	acacia	BEM	30	
Eucalyptus cinerea	silver dollar eucalyptus	BEM	25	55
Laurus nobilis	laurel de olor	BES	30	30
Cedrus atlantica	Atlas cedar	CEL	25	
Pinus halepensis	aleppo pine	CEL	25	50
Pinus pinea	Itailian stone pine	CEM	20	
Juniperus species	juniper	CEM	25	45
Total Sites Planted			500	500

Step 2. For each tree-type, locate the Stored CO_2 by Age and Unit Canopy Look-Up Table (Table 2) for the Inland Valley climate zone at, in this case, 25-years after planting. Copy these values into the Project Index Table (Table 3).

Table 2. The Stored CO_2 by Age and Unit Canopy Look-Up Table contains values for each tree-type in the Inland Valley climate zone at 5-year intervals after planting. Values reflect a single tree's CO_2 per unit tree canopy (TC, kg/m$_2$) at selected years after planting (from McPherson et al. 2016). Values in the highlighted column for 25-year old trees are used in this example.

r TC (kg/m2)	BDL	BDM	BDS	BEL	BEM	BES	CEL	CEM	CES
Age	ZESE	PYCA	PRCE	CICA	MAGR	ILOP	SESE	PIBR2	PICO5
5	2.4	14.3	5.7	4.9	2.6	4.4	6.6	1.2	5.8
10	5.3	17.5	8.6	8.0	5.2	12.0	17.5	5.5	9.4
15	8.0	19.1	11.7	11.0	7.8	19.6	28.6	13.6	12.1
20	10.7	20.3	14.8	14.0	10.3	26.7	40.0	23.5	14.4
25	13.5	21.1	18.0	16.9	12.8	33.1	52.1	24.9	16.4
30	16.2	21.7	21.2	19.8	15.2	38.8	65.0	25.9	18.3
35	18.9	22.3	24.4	22.6	17.5	44.0	79.2	27.0	20.1
40	21.7	22.7	27.6	25.2	19.8	48.8	95.0	28.1	20.1

Step 3. The numbers of trees planted are multiplied by their respective per tree Stored CO_2 index to calculate Project Indices for each tree-type (last column Table 3). These values are summed (10,766 kg) and divided by the total number of trees planted (500) to derive the

Stored CO_2 Project Index (21.53 kg/m^2). This value is the average amount of CO_2 stored per unit of tree canopy (TC), after weighting to account for the mix of species planted.

Table 3. This Project Index Table shows 25-year Project CO_2 indices that are calculated in the fourth column as the products of tree numbers planted (col. 2) and the per tree values for 25-Yr Stored CO_2 (col. 3) from Table 2.

Tree-Type	Number Planted	25-Yr Stored CO2 Indices (kg/m2 TC)	Project Indices (kg/m2 TC)
BDL	120	13.5	1,614.7
BDM	70	21.1	1,475.8
BDS	50	18.0	899.4
BEL	80	16.9	1,355.8
BEM	55	12.8	704.2
BES	30	33.1	992.4
CEL	50	52.1	2,602.5
CEM	45	24.9	1,121.1
CES	0	16.4	0.0
Total:	500		10,766.0
		Project Index:	21.53

Step 4. Use i-Tree Canopy or another tool to classify tree cover and estimate the tree canopy (TC) area for the planted tree sites. If using point sampling, continue adding points until the standard error of the estimate is less than 5%.

Using i-Tree Canopy, 110 points were randomly located in the Project Area (PA) and classified as Tree or Non-Tree. The result was 44.9% tree canopy (TC) and 55.1% non-tree cover, both at ± 4.81% standard error (Std. Er., Table 4). By clicking on the gear icon next to the upper right portion of the image and selecting "Report By Area" the user can prompt i-Tree Canopy to provide an estimate of the area in Tree or Non-Tree cover. In this example, the PA is 12.5 acres.

Table 4. Results from the i-Tree Canopy analysis are percentages of tree and non-tree cover that are converted to area based on the size of the Project Area (PA, 12.5 acres)

	Tree Cover	Non-Tree Cover	Total PA	Std Er.
Percent (%)	44.9	55.1	100	4.81
Area (ac)	5.6	6.9	12.5	
Area (m2)	22,713	27,873	50,585	

Step 5. To estimate the amount of stored CO_2 in the project tree canopy (TC), multiply the Project Index (from Table 3) by the TC area (m^2). Divide by 1,000 to convert from kg to t.

The product of the Project Index (21.53 kg/m^2 TC) and TC (22,713 m^2) is 489,050 kg or 489.1 t CO_2 (Table 5).

Table 5. This table shows that an estimated 22,713 m^2 of tree canopy (TC) stores 489.1 t of CO_2.

	Amounts
Tree Canopy Area (m2)	22,713
Project Index	21.53
Stored CO2 (kg)	489,050
Stored CO2 (t)	489.1

Step 6. Incorporate error estimates and prices to illustrate range of amount stored and value (Table 6).

Table 6. This summary table shows that with 15% of the 489.1 t of CO_2 stored added and subtracted to 489.1 t (see Appendix 1) the actual amount of CO_2 stored is likely to range between 415 t and 562 t. The estimated value, assuming prices of $20 and $40 per tonne, ranges from $8,314 to $22,496.

	CO2 (t)	$ 20.00	$ 40.00
Total CO2 (t):	489.1	$ 9,781	$ 19,562
High Est.:	562.4	$ 11,248	$ 22,496
Low Est.:	415.7	$ 8,314	$ 16,628
± 15% error = ± 10% formulaic ± 3% sampling			
± 2% measurement (see Appendix 1)			

Step 7. Calculate co-benefits (Table 7).

Co-benefits are shown in Table 7 and based on the ecosystem services produced annually per unit TC. Given the 22,713 m^2 of TC after 25 years, total annual services are valued at $8,831, or $18 per site (500 tree sites planted). Estimated energy savings ($5,354) are primarily associated with reductions in air conditioning use due to tree shading and climate effects. Rainfall interception and associated stormwater management savings have an estimated value of $2,565. Uptake of air pollutants by trees is somewhat offset by BVOC emissions, resulting in a net benefit of $532. Avoided CO_2 emissions associated with energy savings is valued at $380 assuming a CO_2 price of $20 per t. These co-benefits are first-order approximations and dollar values may not reflect the most current prices for local environmental and utility services.

Table 7. Co-benefits estimated for the 22,713 m^2 of TC at 25 years after planting 500 trees and calculated using the Inland Valley data found in the i-Tree Streets and Design software. i-Tree prices were used, except for CO_2 , which was $20 per tonne.

Ecosystem Services	Res Units	Total $	$/site
Energy (kWh & kBtu)			
Cooling - Elec.	44,565	$5,196	$10.39
Heating - Nat. Gas	12,679	$158	$0.32
Energy Total		$5,354	$10.71
CO2 Avoided (t, $20/t)	19	$380	$0.76
Air Quality (t)			
O3	0.11	$244	$0.49
NOx	0.03	$168	$0.34
PM10	0.07	$292	$0.58
Net VOCs	-0.08	-$171	-$0.34
Air Quality Total	0.12	$532	$1.06
Rain Interception (m3)	1,245	$2,565	$5.13
Grand Total		$8,831	$17.66

Forward Crediting – Tree Canopy Method (Table 8)

This example (Table 8) forecasts of CO_2 stored in the future tree canopy and assumes that the Registry issues forward credits in the amounts of 10%, 40% and 30% at Years 1, 3 and 5 after planting, respectively. In the example we deduct 10% of the CO_2 stored 25-years after planting to account for likely tree losses. We assume a price of $20 per tonne. The 25-year CO_2 Forecast values (t) were calculated as the product of 90% of the 25-year CO2 Index (kg/m2 TC) values from Table 2 and the No Loss 25-yr TC. The No Loss TC is the product of the 25-yr TC per tree and the number of trees planted.

The 25-year CO2 Forecast (t) values are used to calculate the amount and value of forward credits issued by the Registry assuming a 10% deduction for tree losses. In this example, 90% of the 25-year forecast of CO_2 stored by project trees 25-years after planting is 798.2 t.

Table 8. Forecasted CO_2 credits are based on percentages of amount stored 25-years after planting, assuming a 10% deduction for tree losses and $20/t. The forecasted value of 798.2 t CO_2 stored is the product of the No Loss 25-yr TC (47,140 m^2) and 90% of the 25-yr CO_2 Index (kg CO_2 per m^2 TC). The No Loss TC is the product of the 25-yr TC per tree and the number of trees planted. The No Loss 25-yr TC Forecast is divided by 1000 to convert from kg to tonnes.

Tree-Type	No. Trees	25-yr TC per tree (m2)	No Loss 25-yr TC (m2)	25-Yr CO2 Index (kg/m2 TC)	25-yr CO2 Forecast (t)	10% CO2 (t)	40% CO2 (t)	30% CO2 (t)	10% CO2 ($)	40% CO2 ($)	30% CO2 ($)
BDL	120	158.1	18,967	13.46	229.7	23.0	91.9	68.9	$ 459	$ 1,838	$ 1,378
BDM	70	105.4	7,381	21.08	140.1	14.0	56.0	42.0	$ 280	$ 1,120	$ 840
BDS	50	40.1	2,004	17.99	32.4	3.2	13.0	9.7	$ 65	$ 259	$ 195
BEL	80	101.4	8,112	16.95	123.7	12.4	49.5	37.1	$ 247	$ 990	$ 742
BEM	55	64.4	3,541	12.80	40.8	4.1	16.3	12.2	$ 82	$ 326	$ 245
BES	30	14.4	433	33.08	12.9	1.3	5.2	3.9	$ 26	$ 103	$ 77
CEL	50	55.9	2,797	52.05	131.0	13.1	52.4	39.3	$ 262	$ 1,048	$ 786
CEM	45	86.8	3,905	24.91	87.6	8.8	35.0	26.3	$ 175	$ 701	$ 525
CES	0	39.0	0	16.41	0.0	0.0	0.0	0.0	$0.00	$0.00	$0.00
	500		47,140		798.2	79.8	319.3	239.5	$ 1,596	$ 6,386	$ 4,789

References and Resources

The look-up tables in both examples were created from allometric equations in the Urban Tree Database, now available on-line at: http://www.fs.usda.gov/rds/archive/Product/RDS-2016-0005/. A US Forest Service General Technical Report provides details on the methods and examples of application of the equations and is available online at: http://www.fs.fed.us/psw/publications/documents/psw_gtr253/psw_gtr253.pdf.

The citations for the archived UTD and the publication are as follows.

McPherson, E. Gregory; van Doorn, Natalie S.; Peper, Paula J. 2016. Urban tree database. Fort Collins, CO: Forest Service Research Data Archive. http://dx.doi.org/10.2737/RDS-2016-0005

McPherson, E. Gregory; van Doorn, Natalie S.; Peper, Paula J. 2016. Urban tree database and allometric equations. General Technical Report PSW-253. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.
http://www.fs.fed.us/psw/publications/documents/psw_gtr253/psw_gtr253.pdf

The i-Tree Canopy Tools is available online at: http://www.itreetools.org/canopy/.

Features of ten software packages for tree inventory and monitoring are evaluated in this comprehensive report from Azavea: https://www.azavea.com/reports/urban-tree-monitoring/.

Error Estimates in Carbon Accounting

Our estimates of error include 3 components that are additive and applied to estimates of total CO_2 stored:

Formulaic Error (± 10%) + Sampling Error (± 3%) + Measurement Error (± 2%)

We take this general approach based on data from the literature, recognizing that the actual error will vary for each project and is extremely difficult to accurately quantify. We limit the amount of sampling error by providing guidance on the minimum number of trees to sample in the single-tree approach and the minimum number of points to sample using i-Tree Canopy. If sample sizes are smaller than recommended these error percentages may not be valid. Project Operators are encouraged to provide adequate training to those taking measurements, and to double-check the accuracy of a subsample of tree dbh measurements and tree canopy cover classification. A synopsis of the literature and relevant sources are listed below.

Formulaic Error
A study of 17 destructively sampled urban oak trees in Florida reported that the aboveground biomass averaged 1201 kg. Locally-derived biomass equations predicted 1208 kg with RMSE of 427 kg. Tree biomass estimates using the UFORE-ACE (Version 6.5) model splined equations were 14% higher (1368 kg) with an RMSE that was more than 35% higher than that of the local equation (614 kg or 51%). Mean total carbon (C) storage in the sampled urban oaks was 423 kg, while i-Tree ECO over-predicted storage by 14% (483 kg C) with a RMSE of 51% (217 kg C). The CTCC under-predicted total C storage by 9% and had a RMSE of 611 kg (39%)

Result: Prediction bias for carbon storage ranged from -9% to 14%

Source: Timilsina, N., Staudhammer, C.L., Escobedo, F.J., Lawrence, A. 2014. Tree biomass, wood waste yield and carbon storage changes in an urban forest. Landscape and Urban Planning. 127: 18-27.

The study found a maximum 29% difference in plot-level CO_2 storage among 4 sets of biomass equations applied to the same trees in Sacramento, CA. i-Tree Eco produced the lowest estimate (458 t), Urban General Equations were intermediate (470 t, and i-Tree Streets was highest (590 t).

Source: Aguaron, E., McPherson, E.G. Comparison of methods for estimating carbon dioxide storage by Sacramento's urban forest. pp. 43-71. In Lal, R. and Augustin, B. (Eds.) Carbon Sequestration in Urban Ecosystems. New York. Springer.

Sampling Error
This error term depends primarily on sample size and variance of CO_2 stored per tree. If sample size is on the order of 80-100 sites for plantings of up to 1,000 trees, and most of the trees were

planted at the same time, so the standard deviation in CO_2 stored is on the order of 30% or less of the mean, then the error is small, about 2-4%.

Source: US Forest Service, PSW Station Statistician Jim Baldwin's personal communication and sample size calculator (Sept. 6, 2016)

Measurement Error
In this study the mean sampling errors in dbh measurements with a tape were 2.3 mm (volunteers) and 1.4 mm (experts). This error had small effect on biomass estimates: 1.7% change (from 2.3 mm dbh) in biomass calculated from allometric equations.

Source: Butt, N., Slade, E., Thompson, J., Malhl, Y., Routta, T. 2013. Quantifying the sampling error in tree census measurements by volunteers and its effect on carbon stock estimates. Ecological Applications. 23(4): 936-943.

Appendix C

Verification

[This is an outline of Verification for your review and comment. Specific language and standards are being developed and will be coming.]

The Registry will verify compliance with this Protocol per International Standards Organization 14064-3. Specifically, the Registry adopts and utilizes the following standards from ISO 14064-3:

1. Upon receiving a Project Report with updated data on eligibility, quantification of carbon and co-benefits, and a request for credits, the Registry will verify a project's compliance with this Protocol.
2. A peer reviewer will audit the Registry's verification, utilizing standards to be adopted by the Registry.
3. The Registry will verify all sampled trees for both the Single Tree Method and the Tree Canopy Method, as well as for the issuance of Forward Credits.
4. The Registry will also adopt standards for geocoded photographs, landmarking, images of trees or canopy areas and any other data necessary to conduct verification.
5. The Registry will develop a database to record, store, and track the quantification and verification data.
6. The Registry will develop a risk assessment standard to provide a cross-check on data collection and review.
7. The Registry will adopt a process for follow-up and maintenance for consistency and continuity.

The following summarizes the basic verification processes:

- Verification will be conducted by a verification official at the Registry, with review by a peer reviewer.
- For the Single Tree Method, the Project Operator will provide geocoded photographs with species and DBH (diameter at breast height) for a verification subsample of sampled Project trees. The Registry verification official will then confirm that the photographed species and DBH match the data submitted as "recorded in the field" and are consistent with data from the original Project Plan.

- For the Tree Canopy Method, the Project operator will submit to the Registry the i-Tree Canopy file that they developed, including locations used to calculate canopy area. The Registry verification official will independently estimate canopy area for the same project area.
- For projects requesting forward credits on the tiered release in Section 2.3.B, the Project Operator will send to the Registry geocoded photographs of a sampling of project trees or canopy, or provide maps or images from Google Earth or other accepted imaging standards that allow verification of a sample of Project trees.
- Project Operators may use data from management or maintenance activities regularly conducted if the data was collected within 12 months of the project's request for credits.

Urban Forest Carbon Protocols

Appendix D: Discussion of Carbon Protocols and Principles

Draft

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TABLE OF CONTENTS

This Appendix D of the protocols contains a detailed discussion of the principles and standards applicable to carbon protocols in general and the development of the specific requirements in the Urban Forest Tree Planting Protocol and the Urban Forest Tree Preservation Protocol.

1. General Standards of Protocol Development

No single authoritative body regulates carbon protocols or determines final standards. The Stockholm Environment Institute's Carbon Offset Research and Education resource lists the various institutions and programs that have set out formulations of basic principles that every carbon offset protocol should contain. (See CORE at http://www.co2offsetresearch.org/policy/ComparisonTableAdditionality.html).

CORE lists twenty-five different programs or institutions that have either developed standards for protocols or issued standards and rules for their own programs. These institutions range from international bodies such as the Kyoto Protocol, the World Resources Institute, and the International Organization for Standardization, to U.S. carbon programs such as the Regional Greenhouse Gas Initiative and Midwest Greenhouse Gas Reduction Accord, to registries such as the American Carbon Registry, the Climate Action Reserve, and the Verified Carbon Standard.

The standards issued by these bodies vary, and the specific rules formulated to give content to these different standards vary even more. For example, the Clean Development Mechanism under the UN Framework stemming from the Kyoto Protocol lists 115 different approved baseline and monitoring methodologies for large scale offset projects.

To complicate matters more, the environmental and carbon community have tolerated a de facto different standard between compliance protocols and voluntary protocols. Compliance protocols exist in cap and trade jurisdictions like California. Because these compliance protocols establish the rules for credits that will offset actual regulated GHG emissions from monitored sources, greater rigor is expected than in voluntary protocols, where purchasers are buying credits voluntarily to reduce their carbon footprint, not to offset regulated emissions.

There is, nonetheless, a general consensus that all carbon offset protocols must contain the following:

- Accounting Rules: offsets must be "real, additional, and permanent." These rules cover eligibility requirements and usually include baselines for additionality, quantification methodologies, and permanence standards.

- Monitoring, Reporting, Verification Rules: monitoring, reporting, and verification rules ensure that credits are real and verifiable.

Certification, enforceability, and tracking of credits and reversals are performed by specific programs or registries, guided by language in the protocol where relevant.

Over the last ten years, several documents setting forth standard and principles for protocols have emerged as consensus leaders for programs attempting to develop their own offset protocols for specific project types. We will follow and refer most often to:

- World Resources Institute/WBCSD GHG Protocol for Project Accounting ("WRI Protocol Guidelines");

- Clean Development Mechanism, Kyoto Protocol, now part of the UN Framework Convention on Climate Change ("CDM").

1.1 Recognition of Distinct Urban Forest Issues in Protocol Development

The task for the Urban Forest Drafting Group was to take the principles and standards set forth in these foundational documents and adapt them to urban forestry. As we described briefly in the Introduction to the Urban Forest Protocols, urban forestry and its potential carbon projects are different than virtually all other types of carbon projects:

- Urban forests are essentially public goods, producing benefits far beyond the specific piece of land upon which individual trees are planted.

- New tree planting in urban areas is almost universally done by non-profit entities, cities or towns, or quasi-governmental bodies like utilities. There are no for-profit entities in the U.S. that engage in new tree planting as their main business.

- Except for a relatively small number of wood utilization projects, urban trees are not merchantable, are not harvested, and generate no revenue or profit.

- With the exception of very recent plantings begun in California using funds from its Greenhouse Gas Reduction Fund, no one currently plants urban trees with carbon as a decisive reason for doing the planting.

- Because urban tree planting and maintenance are expensive relative to carbon revenues, urban forestry has not attracted established for-profit carbon developers.

- Because urban forest projects will take place in urban areas, they will be highly visible to the public and easily visited by carbon buyers. This contrasts with most carbon projects that are designed to generate tradeable credits purchased in volume by distant and "blind" buyers.

The WRI Protocol Guidelines recognize explicitly that the principles underlying carbon protocols need to be adapted to different types of projects. The WRI Protocol Guidelines further approve of balancing the stringency of requirements with the need to encourage participation in desirable carbon projects.

During the drafting process, we remained mindful at all times that the above unique factors of urban forestry distill down to three central attributes:

1. Urban trees deliver a broad array of documented environmental benefits,

2. Urban trees are essentially a public good delivering their array of environmental benefits to the people and communities living in cities and towns – almost 80% of the population, and

3. There are little to no harvests, revenues, or profits for those who preserve and grow the urban forest.

These three key attributes lead to the conclusion that urban forest projects are highly desirable, bringing multiple benefits to 80% of the population in a public good that is unlikely to be gamed or exploited.

Our task then was to draft urban forest protocols that encouraged participation in urban forest projects, while also addressing not just the principles of carbon protocols, but the policies underlying those principles.

2. Additionality

The rationale for additionality is simple: since carbon projects are offsets to emissions, they need to sequester additional carbon, not just give credits for carbon that would have been sequestered anyway.

The policy underpinnings of additionality seek to address two evils: no net carbon reductions and unjust enrichment to those who conduct business as usual.

What follows is an extended discussion of additionality. We begin by returning to the foundational principles and policies underlying the concept of additionality, particularly as set out in the WRI Protocol Guidelines.

We discuss the project-specific methodology and the perverse incentives that methodology creates for urban forestry. We set out the performance standard methodology and apply it to urban forestry, with data and a conclusion. And last, we discuss the legal requirements or regulatory surplus test and apply it to urban forestry.

We note at the outset of this discussion that the Registry is working to establish a 40-year buffer (reserve) pool of additional forest carbon to collateralize or insure the urban carbon stored in Project trees. This buffer or reserve pool will act as insurance or collateral for forty years for the urban carbon stored in projects under the Registry.

2.1 Summary of Relevant Portions of the WRI Protocol Guidelines

What follows now is a summary of the guidelines on additionality set forth in the WRI Protocol Guidelines. These guidelines clearly show the flexibility that the WRI intended to build into the development of carbon protocols.

The WRI Protocol Guidelines builds its additionality requirement into its baseline requirement for carbon projects. It also discusses various further or add-on additionality tests, like the legal requirements test, but it states that those additionality tests are entirely discretionary and depend on policy factors within the purview of the project developers. The WRI Protocol Guidelines indicates explicitly the need for flexibility for different project types:

The concept of additionality is often raised as a vital consideration for quantifying project-based GHG reductions. Additionality is a criterion that says GHG reductions should only be recognized for project activities that would not have "happened anyway." While there is general agreement that additionality is important, its meaning and application remain open to interpretation. The Project Protocol does not require a demonstration of additionality per se. Instead, additionality is discussed conceptually in Chapter 2 and in terms of its policy dimensions in Chapter 3. Additionality is incorporated as an implicit part of the procedures used to estimate baseline emissions (Chapters 8 and 9), where its interpretation and stringency are subject to user discretion.

While the basic concept of additionality may be easy to understand, there is no common agreement about how to prove that a project activity and its baseline scenario are different.

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. For example, a focus on environmental integrity may necessitate stringent additionality rules. On the other hand, GHG programs that are initially concerned with maximizing participation and ensuring a vibrant market for GHG reduction credits may try to reduce "false negatives"—i.e., rejecting project activities that are additional—by using only moderately stringent rules.

…There is no agreement about the validity of any particular additionality test, or about which tests project developers should use. ***GHG programs must decide on policy grounds whether to require additionality tests, and which test to require. Because their use is a matter of policy, the Project Protocol does not require any of these tests.***

As the language above makes clear, additionality does not have to be applied on a project-specific basis. In fact, additionality is not a rule to be applied inflexibly, but rather a concept to be developed and adjusted for the context of each type of carbon project. The baseline methodology set out by the WRI allows for that kind of customization.

2.2 Project-Specific Methodology

Many people think of additionality as applied only on a project-specific basis, with the specific project or specific project developer being required to show that it reduced emissions (or removed them from the atmosphere) beyond its business-as-usual practices.

In the urban forest context, this produces immediate anomalies:

- Entities with a commitment to or even recent practice of tree planting and who begin carbon projects would get far fewer carbon credits than entities with no historical commitment to urban trees. To use the language of baselines, the baseline of entities that plant trees would be the trees they have annually planted, while the baseline of entities that plant no trees would be zero.
    - The City of Los Angeles has launched its Million Tree LA initiative (now CityPlants). These voluntarily planted trees would generate no carbon credits for LA, whereas a city like Bakersfield, which plants few to no trees, would get carbon credits for every tree it planted.

- The same result obtains for an entity like the Sacramento Municipal Utility District, which voluntarily plants over 15,000 trees per year.

- If additionality is applied inflexibly on a project-specific basis, then entities that plant trees now would have the perverse incentive to stop their planting, even temporarily, to bring their own business-as-usual baseline to zero.

- Governments with progressive tree ordinances or land use regulations that seek to increase canopy cover, would get fewer carbon credits because trees planted per their regulations would be part of their baseline and thus not eligible for crediting. Inflexible application of this "legal requirements" test leads to the perverse incentive for cities to leave their trees unregulated and unprotected.

2.3 Performance Standard Methodology

But there is a second additionality methodology set out in the WRI 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 standard using the data from many other projects with similar activities over geographic and temporal ranges justified by the developer.

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

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

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.

A. Data on Tree Canopy Change over Time in Urban Areas

Our 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:

Changes in Urban Tree Canopy (UTC) by Region (from Nowak and Greenfield, 2012)

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	

Absolute change is based on city land area
Relative percent change is based on percentage of UTC
Average annual change in UTC in hectares per year
Average annual change in UTC in hectares per capita per year

These data show that urban tree canopy is negative in all four regions. Even though there may be individual tree planting activates that increase the number of urban trees within small geographic locations, the urban tree canopy is declining in all cities but one in this data set, and is declining in every region.

The regional baselines from this data provide baselines for all projects within those regions. The Drafting Group did not use negative baselines for the Tree Planting Protocol, but determined to use baselines of zero.

Our deployment of the Performance Standard baseline methodology for an Urban Forest 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 trees that are protected from removal.
- Because few trees are planted now with carbon as a decisive factor, urban tree planting done to sequester and store carbon is additional;
- Because virtually all new 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 UF carbon projects.

2.4 Legal Requirement Test (also called the Regulatory Surplus Test)

The WRI Protocol Guidelines discuss the so-called Legal Requirement Test. This is identified in the UN's Clean Development Mechanism as the Regulatory Surplus Test. These tests disqualify any credits for carbon stored to meet a pre-existing legal requirement. In other words, the carbon stored must be surplus to carbon stored per legal or regulatory requirements.

If these tests are applied literally, then any tree planted per a city ordinance or code for any reason, such as shade trees for parking lots, would not be additional. But in fact, the WRI Protocol Guidelines state clearly that application of the Legal Requirement Test is optional. Among the factors relevant to that decision are policy considerations such as other co-benefits from a project or whether a too-stringent application of the test will limit participation in the protocol. Give the documented co-benefits of urban trees, including potential environmental justice, and given the national decline in tree canopy, there is a persuasive case for eschewing the legal requirements test altogether.

But the Drafting Group determined that the Urban Forest Tree Planting Protocol should declare ineligible trees that are planted on private property due to an enacted ordinance or law. We intend this to exclude trees required to be planted on private property by enacted ordinances or laws.

Some cities have policies of replacing trees on public property, but these policies are advisory and do not rise to the compulsion of an enacted ordinance. Moreover, trees planted on public property confer no private benefit, so that there is no danger of unjust enrichment.

Our development of a legal requirement test that declares ineligible trees required by ordinance or law to be planted on private property is supported because the baseline of the urban tree canopy is negative.

Moreover, the WRI Protocol Guidelines explicitly allow a balancing of stringency with the need for participation in desirable project types. Given the many environmental benefits of urban trees, delivered to the 80% of the population that lives in cities and towns, our legal requirements test is appropriate.

2.5 Additionality in the Tree Preservation Protocol

Our Drafting Group modeled the Tree Preservation Protocol on the "Avoided Conversion" type of project for forest land. We have provided that urban trees that are under threat of removal, and that are protected from removal, should be eligible to earn carbon credits.

The Avoided Conversion model that we borrowed from the forest context rests on a simple and common sense idea. Forested parcels that are protected from development are additional in that they would have been removed by the development. Therefore, the owners of that protected land should be able to earn carbon credits for those trees protected from development.

Additionality per se is generally not in dispute in forest Avoided Conversion projects. The trees that would have been cut down for development are saved, therefore they are additional from the time they are preserved from development. Every day they are protected from removal is an additional day of CO2 storage in those trees.

But the simple idea of avoided conversion has proven difficult to capture in the rules of most forest Avoided Conversion protocols. For it is based on two real-world problems. First, proving that trees would be lost to development is counter-factual. How can a project developer show something that has not happened but that is supposed to be imminent and inevitable? If the land ends up being protected from development such that it could qualify for avoided conversion carbon credits, then development of the land could not have been inevitable after all.

This counter-factual predicament is magnified by the failure of most forest Avoided Conversion protocols to identify and define the two key underlying elements of a threat of conversion, which are imminence and inevitability. Because these two key parts of the threat of conversion are not clearly identified and addressed, the rules can become either too vague or overly detailed.

Second, for the Avoided Conversion forest protocol to be consistent with general carbon protocol principles, a project developer should show not only that the land would have been developed, but also that it was saved from development for the carbon storage of the trees on it. If the land was saved for reasons other than carbon storage, then that storage and those carbon credits would not be additional. Yet, we are not aware of an Avoided Conversion forest protocol that addresses this issue.

What does seem clear in both the forest and the urban forest context is that any tree preserved from removal is additional. And the CO2 stored in those preserved trees is additional for as long as those trees are standing.

Moreover, we know from the baseline data utilized to develop the performance standard that urban tree cover is declining. The baseline is negative. This means that the difference between the negative baseline and zero is all additional. For the Tree Planting Protocol, the Drafting Group decided to use a baseline of zero, in effect ignoring the negative baseline. But for Tree

Preservation projects, the negative baseline adds support for the additionality of any tree preserved. Any tree protected from removal within the delta of the negative baseline and zero is additional.

As with the forest Avoided Conversion protocols, we have not tried to parse the meanings of imminence and inevitability. Doing this seems more important for forest projects, because forest lands have widely varying threats of removal. Forest land near rural cities or towns is at much higher risk than forest land remote from human settlement.

Most urban trees on private property, by contrast, are under a continual background threat. The simple but inexorable force of land values in urban areas gives a higher value to land with built improvements than bare land with trees. The only workable tools to mitigate this threat of removal are public ownership of land, laws protecting urban trees from removal during development, and some form of financial incentive, such as carbon revenues, to preserve urban trees.

For purposes of the Urban Forest Tree Preservation Protocol, we follow the Avoided Conversion forest protocols in that we do not define imminence or devise a set of rules to demonstrate it per se. Rather, we set out the protections required to preserve trees from removal or conversion. We also set out a list of factors that a Project Operator could select from to show the threat of conversion. These factors include a threshold land price, a zoning designation indicating a higher developed use, and others.

If a project operator shows those threats, then the trees preserved from removal are additional from the day they are preserved. We have based the crediting on a 40-year project duration. But because any time that trees under threat of removal are preserved is additional, we have allowed projects with a Preservation Commitment of less than 40 years to earn credits, but reduced by the same percentage as the years of preservation are less than 40. And we do not allow preservation projects of under 20 years.

3. Permanence

Permanence embodies the principle that carbon stored should not be reversed. Here is the WRI Protocol Guidelines summary of Permanence:

Emission reductions or removals are permanent if they are not reversible; that is, the emissions can’t be rereleased into the atmosphere. The issue of permanence applies to projects where emissions are sequestered in ways that could be reversed over time, such as in forests (which can release carbon through fires or decay) and through geological sequestration (where gases could potentially leak unexpectedly). *There are mechanisms to account for or reduce the risk of* *reversal, though they can bring additional costs. These include buying insurance in case of emissions reversals, establishing a reserve "buffer" pool of credits or issuing temporary credits from the project that are valid for a period of time but must be re-certified or replaced in the future.* [Emphasis supplied]

The above language specifically refers to "buying insurance," creating a buffer or reserve pool, and even issuing temporary credits. The Registry is working to establish a 40-year buffer (reserve) pool of additional forest carbon to collateralize or insure the urban carbon stored in Project trees. This buffer or reserve pool will act as insurance or collateral for forty years for the urban carbon stored in planting projects under the Registry.

3.1 Time Period

This statement makes no reference to a time requirement for permanence. Rather, the permanence requirement focuses on reversals. This makes sense, because if carbon storage is never reversed, then no time period is necessary. But few human efforts are "never" reversed or truly permanent.

So, the Climate Action Reserve, to take one example, follows the IPCC lead and imposes a 100-year permanence requirement on all of its protocols, with reversal mechanisms for projects that receive progress credits before their 100-year period. But even 100-year carbon storage is not permanent, and carbon stored for those 100 years has no guarantee of staying stored at the end of the 100 years.

Other protocols have adopted a 40-year project duration, preferring to use terms like "Minimum Project Commitment" rather than Permanence. (see Improved Forest Management on American Carbon Registry, for example) The Regional Greenhouse Gas Initiative was willing to accept a 40-year permanence period for its offset projects. Still others have developed risk calculators or assessments, with a sliding scale of "permanence."

So it is clear that many developers of protocols have struggled to create a permanence requirement. The 100-year period of the Climate Action Reserve and the 40-year period of the American Carbon Registry and RGGI are two examples. But it is difficult to reconcile the 60-year difference between these two duration requirements.

Our response to this issue is to establish a 40-year buffer or collateral pool of CO_2 to back up the urban CO_2 stored in urban forest planting projects. Because the urban CO_2 is backed up for 40 years, we can then set a project duration that will work for urban forestry – 25 years.

The years past 25 will result in the greatest CO_2 storage, so projects have a strong incentive to continue.

The Drafting Group felt strongly that, because most urban forest projects are funded and executed by cash-short cities and towns and local non-profits, a 40-year commitment will render the protocol unusable. Even a 25-year duration may eliminate worthy projects. But in any event, the CO_2 stored in 25-year urban projects is backed up for 40 years.

Some of the unique factors of urban forestry support our method of addressing the permanence issue:

- No one harvests the urban forest, so there is no danger of a Project Operator choosing to terminate its carbon project to reap the profits of harvest. Termination of a forest project for harvest, on the other hand, is a quite real danger where owners are continually assessing the costs and revenues of carbon storage against the profits of harvest.

- With no threat of harvest looming, an urban tree that survives into its second or third decade has a strong probability of surviving for many more years.

- If an urban forest carbon project receives credits for carbon storage at year 15, for example, the carbon storage will grow as the trees grow, so that incidental mortality will likely not lower the carbon stored in that project.

- It is highly unlikely that an entire urban forest will be destroyed by a fire or disease, as can happen with forest land. Most cities have a diversity of species that would mitigate the effect of a disease that afflicted a species.

- Urban forests need to have diversity of species and age, as well as functional diversity. Different species perform certain functions better than others (reducing pollution, providing certain health benefits), and a diverse and healthy urban forest needs to reflect that functional diversity as well as age and species.

- Urban trees are expensive to plant and maintain. Even if urban forest credits commanded a price of $20 per tonne, carbon revenues will likely defray only 5 to 30% of the costs of planting and maintaining a tree. Given the many benefits of urban trees beyond carbon storage, a permanence period must not be so long as to choke participation in these important projects.

- Dynamic land uses and property ownership in cities and towns makes a long permanence period impossible.

- A significant percentage of urban forest funding decisions are made by elected officials. We may hope that our elected officials have a long-term view of our cities and towns, but all too often the time horizon of elected officials is the election cycle. A long permanence period will dramatically discourage most elected officials from promoting participation in urban forest carbon projects.

- Many analysts predict that renewable energies will overtake fossil fuels in 20 years. If that is the case, our permanence goal would be a bridge to those renewable energy sources in 20 years.

For all of these reasons, our Drafting Group determined that a 25-year Project Duration period was the best time period to adapt the principles underlying the permanence standard to urban forestry. We believe that most projects will continue long past the 25-year Project Duration. Projects have every incentive to do so, because they could earn carbon credits after that period, having already invested in making a project successful for its first 25 years.

We have also included specific rules on reversals, so that credits reflecting carbon stored must be earned or compensated.

4. Issuance of Credits

With respect to the issuance of credits, our urban forest protocols break ranks with most carbon protocols and registries in a significant way:

- We will issue so-called Forward Credits; i.e., we will issue credits early in projects, before carbon has been actually stored and quantified.

We understand the strong antipathy for forward credits and the reasons underlying that antipathy. But with the urban CO2 fully backed up by forest CO2 for 40 years, the Forward Credits we issue will be completely insured. There can be no objection to Forward Credits if the credits are fully buffered or collateralized in a duplicate stock of CO2.

Here are the reasons we have developed Forward Credits and why they make sense for both projects and carbon buyers.

4.1 Forward Credits

Forward credits in an urban forest tree planting protocol are not merely desirable, they are indispensable. Almost no urban forest projects can wait for 25 years to receive funding. Elected and agency officials are all too often required to plan with the timeline of an election cycle, not a Permanence standard in a carbon protocol and not a 25-year waiting period for tree growth and carbon storage.

So our challenge was to develop a forward crediting method that would provide assurance to carbon buyers that the carbon reflected in a Forward Credit would be stored. We needed to find a way to show the buyers that any Forward Credits issued are, in effect, guaranteed.

We note first that our society has developed many mechanisms analogous to a Forward Credit where a person or entity receives money or something of value, and then performs a service or pays that money back over time:

- A bond issuer receives the proceeds of a bond in year 1, and then pays that bond back over time.
- A homeowner receives mortgage loan proceeds to purchase a house, and then occupies the house while paying back the mortgage loan over time.
- A contractor receives partial payment before beginning work, and delivers the service over time.
- A landlord receives rent at the beginning of a month and delivers a habitable swelling unit over the next month.

In all these examples, and many more, the parties have agreed to an early delivery of money in exchange for some type of performance later. They have dealt with the risk of later nonperformance by negotiating mechanisms that reduce that risk to acceptable levels. A mortgage lender, for example, requires a minimum loan to value ratio and also a security interest or deed of trust on the property purchased with the loan proceeds. With these in place, the lender has reduced its risk to acceptable levels. Similarly, a bond holder receives less interest the higher the credit rating of the bond issuer and the bond. The bond holder in effect pays more for a more secure promise of later performance.

The large carbon registries have been wary of early issuance of credits, because they have been justifiably worried that carbon developers will take the money and run; i.e., that the carbon developers will not perform their promise to store carbon after credits have been issued.

Our task for the urban forest protocol then, given that we need to issue Forward Credits to make urban forest carbon projects possible, was to analyze potential urban forest carbon projects to determine where the risks were. Where and what, we asked, are the risk points in urban forest projects? Where could projects fail, or be abandoned? And how can we assure performance or coverage around those risk points, so that a Forward Credit is essentially guaranteed to do what it promises, which is to store carbon for a defined time period.

A. Risk Points

Here are the risk points we identified in tree planting projects:

- Will the Project Operator plant the trees?
- Will the trees survive past year 3, given that mortality is higher in the early years of an urban tree's life than in later years?
- Will the trees survive past year 5, given that data supports the conclusion that mortality drops significantly after year 5?
- Are there risk points for large scale mortality due to disease, fire, natural disaster, and other events?
- Is there a risk that the Forward Credits issued will represent more carbon than is actually stored in project trees by the end of the project?

To address the first three and the fifth of these risk points, we developed a tiered or staircase release of Forward Credits, triggered by a Project Operator's demonstration that it has passed particular risk points:

1. After planting of project trees: 10% of projected total carbon stored by Year 26;
2. After Year 3: 40% of projected total carbon stored by Year 26;
3. After year 5: 30% of projected total carbon stored by Year 26;
4. At the end of the 25-year Project Duration and after quantification and verification of carbon stored: "true-up" credits equaling the difference between credits already issued (which were based on projected carbon stored) and credits earned based on quantified and verified carbon stored;
5. 5% of total credits earned will be retained by the Registry at the last issuance of credits to a Project for use in a Registry-wide Reversal Pool;

Forward Credits are thus released only after a project successfully passes through a risk point. And 10% of projected credits are withheld until the end of the project, when a true-up of Forward Credits with carbon stored occurs.

The fourth risk point – fire, disease or some cataclysmic event – we consider remote. A forest fire can sweep through a large stand of forest. But urban fires rarely consume large areas. Some diseases, like Dutch Elm Disease, can over time devastate a species, but most cities have learned the lessons of Dutch Elm Disease and plant a variety of species. Nonetheless, to insure against that unlikely risk of cataclysm, we have provide for retention of 5% of credits earned in a Buffer Pool, to be held by the Registry.

As final and tertiary level of absolute assurance, we repeat that we are working to establish a pool of forest CO2 as a buffer or collateral pool to back up the Forward Credits. This buffer pool will provide a third layer of protection for any buyer concerned that an urban forest project will not store the CO2 promised.

5. Quantification

Quantification methods for Tree Planting projects are set out in Appendix B. The two methods are the Single Tree Method, for smaller projects or trees planted non-contiguously, and the Tree Canopy Method, for trees planted in groups.

We are currently developing a quantification method for Tree Preservation projects. We debated offering the two methods above plus a method more akin to quantification of forest carbon. But we have concluded provisionally that larger parcels of standing and contiguous trees require a quantification method that reflects those types of stands and carbon storage.

In addition, the Tree Preservation protocol needs a baseline to deduct for trees that would have remained if the property had been developed (i.e., converted to a developed use).

We will update the protocol and this document as soon as possible.

6. Verification

We still have more development work to do on Verification, but we have set out the basic outlines in the protocols and in Appendix C on Verification.

Verification is yet another area where the reality of urban forest projects collides with customary practice at large carbon registries and large carbon projects. The scale of the large carbon projects, and the potential revenues, allows for the costs of third-party verification, usually done by professional firms whose fees are substantial.

It was clear to the Drafting Group that many urban forest projects would not be able to afford to pay the substantial fees charged by third-party verification firms. The third-party verification fees would be the single largest expense of many urban forest carbon projects and would cannibalize the revenues.

Rather than impose verification costs on individual projects, we developed a verification method at the program level. As the protocols and Appendix C set out, we will perform verification at the Registry level, using the standards in ISO 14064-3. The use of geocoded photographs and updated images will help reduce the costs of verification to a manageable level.

We will supplement this discussion as we develop the specific requirements and standards for verification.