URBAN FOREST CARBON REGISTRY

Tree Planting Protocol

Public Comment
Version 4

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Abbreviations and Acronyms

C	Carbon

CO2	Carbon dioxide
DBH	Diameter at Breast Height
GHG	Greenhouse gas
ISO	International Organization for Standardization
PIA	Project Implementation Agreement
PO	Project Operator
Registry	Urban Forest Carbon Registry

Introduction

This Urban Forest Carbon Protocol sets forth the requirements for Tree Planting projects in urban areas in the U.S. to quantify carbon dioxide sequestration from woody biomass. That woody biomass is referred to herein by the broader term "urban forest."

This protocol provides eligibility rules, methods for quantifying biomass and CO_2 storage, and reporting, monitoring, issuance of credits, reversal, and verification requirements. We have been guided in our drafting by one of the foundational documents for carbon protocols, the World Resources Institute/World Business Council for Sustainable Development Greenhouse Gas Protocol for Project Accounting, which describes greenhouse gas ("GHG") project accounting principles. We refer to this document as the WRI GHG Protocol.

Our goal is in this protocol is to provide for accounting of net GHG reductions is a consistent, transparent, and accurate manner, consistent with the principles and policies set forth in the WRI GHG Protocol document. This process will form the basis for GHG reductions that are real, additional, permanent, verifiable, and enforceable, which can then result in the issuance by the Urban Forest Carbon Registry of carbon offset credits, called City Forest Carbon+ Credits™.

Urban forests in the U.S. are estimated to store over 643 million tonnes of CO_2. [1] The co-benefits of urban forests include air quality improvements, energy savings from reduction of the urban heat island effect, slope stability, bird and wildlife

[1] Nowak, David J., et al. "Carbon storage and sequestration by trees in urban and community areas of the United States." *Environmental Pollution* 178 (2013): 229-236, 231.

habitat, sound and visual buffering, public health improvements, safety, livability, social cohesiveness, economic improvements, and more.[2] Urban trees clearly influence air temperatures and energy and affect local climate, carbon cycles, and climate change.[3]

Moreover, almost 80% of the population worldwide lives in urban areas, and urbanization is a significant demographic trend of the 21st century. The array of benefits delivered by urban trees directly links to human health and life in cities and towns.

Documents and Standards for 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.[4]

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.

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[2] See Alliance for Community Trees, Benefits of Urban Forests: a Research List at http://www.actrees.org/files/Research/benefits_of_trees.pdf

[3] Nowak, 229

[4] See CORE at http://www.co2offsetresearch.org/policy/ComparisonTableAdditionality.html

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, 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 fifteen 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:

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

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. 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, quasi-governmental bodies like utilities, and private property owners.
- 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.

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

- Urban trees deliver a broad array of documented environmental benefits,
- 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
- 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 through highly-credible protocols that addressed not just catch-phrase principles of carbon protocols, but the policies underlying those principles. Where the needs of urban forest practicality required a variance from accepted principles of carbon protocols, we developed solutions to those variances to maintain a high level of stringency.

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 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 of any credits for carbon storage or other benefits delivered by Project trees on that landowner's land. If Project trees are on private property, this agreement must be recorded in the property records of the county in which the land containing Project trees is located.

2. Additionality

The Registry ensures additionality through the following three requirements – 1) a pool of forest carbon to back up all urban carbon (Section 2.1), 2) a performance standard baseline developed in adherence with the WRI GHG Protocol (Section 2.2), and 3) a Legal Requirements Test that declares trees planted due to an enacted law or ordinance not eligible (Section 2.3).

2.1 Back-Up Pool of Additional Forest CO2

The Registry is establishing a 40-year pool of additional forest carbon to back up or collateralize the urban carbon stored in Planting Project trees. Credits earned by urban forest planting projects and issued by the Registry thus will consist of two stocks of CO_2, one reflected in credits issued to urban forest planting projects, and a second stock in a block of additional forest CO_2 for 40 years.

2.2 Performance Standard Baseline per WRI GHG Protocol

Additionality is often 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:

- Organizations that plant trees on a regular basis 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 anomaly would occur for an entity like the Sacramento Municipal Utility District, which voluntarily plants thousands of 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.

Performance Standard Methodology

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

We understand that a common perception is that projects must meet a project specific test. Project-specific additionality is easy to grasp conceptually. The 2014 Climate Action Reserve urban forest protocol essentially uses project-specific requirements/methods.

However, the WRI GHG Protocol clearly states that either a project-specific test or a performance standard baseline is acceptable.[5] One key reason for this is that regional or national data can give a more accurate picture of existing activity than a narrow focus on one project or organization.

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

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

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

Table 2.1 Performance Standard Factors

WRI Perf. Standard Factor	**As Applied to Urban Forestry**
Describe the project activity	Increase in urban trees
Identify the types of candidates	Cities and towns, quasi-governmental entities like utilities, watersheds, and educational

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

	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.[6]

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.

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

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:

Table 2.2 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 large-scale urban tree planting is conducted by governmental entities or non-profits, or by private property developers complying with governmental regulations (which would not be eligible for carbon credits under our protocol), and because any carbon revenues will defray only a portion of the costs of tree planting, there is little danger of unjust enrichment to developers of UF carbon projects.

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

Setting the stringency of additionality rules involves a balancing act. Additionality criteria that are too lenient and grant recognition for "non-additional" GHG reductions will undermine the GHG program's effectiveness. On the other hand, making the criteria for additionality too stringent could unnecessarily limit the number of recognized GHG reductions, in some cases excluding project activities that are truly additional and highly desirable. In practice, no approach to additionality can completely avoid these kinds of errors. Generally, reducing one type of error will result in an increase of the other. Ultimately, there is no technically correct level of stringency for additionality rules. GHG programs may decide based on their policy objectives that it is better to avoid one type of error than the other.[7]

2.3 Legal Requirements Test: Legally Required Trees Not Eligible

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

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

In summary, the three elements developed above to address additionality – the 100% back-up pool of forest carbon, the performance standard baseline, and the legal requirements test - reflect both the principles and the explicit language of the WRI GHG Protocol and give security on additionality.

3. Project Duration

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

The Registry is establishing a 40-year pool of additional forest carbon to back up or collateralize the urban carbon stored in Planting Project trees. Credits earned by urban forest planting projects and issued by the Registry thus will consist of two stocks of CO_2, one reflected in credits issued to urban forest planting projects, and a second stock in a block of additional forest CO_2 for 40 years.

This 100 percent back-up pool in place for 40 years thus allows a 25-year Project Duration Commitment for urban forest planting projects.

4. 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.

5. Project Commencement

A Project commences when the Registry approves a Project Operator's application.

6. Issuance of Credits for Tree Planting Projects

The Registry will issue City Forest Carbon+ Credits™, representing a metric tonne of carbon, bundled with the quantified co-benefits of storm water run-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 Forward Credits and Credits Issued at End of Project

The Registry is establishing a 40-year pool of additional forest carbon to back up the urban carbon stored in Planting Project trees. This second stock of carbon allows the Registry to issue Forward Credits as follows, because the forest carbon stock backs up or collateralizes the performance of the urban Forward 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: all remaining credits issued after Final Quantification and verification of carbon stored. Twenty percent of projected credits are withheld until the end of the project. At that point, the Project Operator will conduct a Final Quantification. At that time, the Registry will issue "true-up" credits equaling the difference between credits already issued (which were based on projected carbon stored) and credits earned based on Final Quantification and verification of carbon stored;

E. 5% of total credits earned will be retained by the Registry for 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 Forward Credits

A. The Registry will retain 5% of total credits earned as a program-wide reversal pool.

B. If a project has received more Forward Credits than it has earned based on the Final Quantification at the end of the project ("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. Projects must comply with all applicable requirements of this Protocol.

If a project chooses to continue into a second 25-year Project Duration, the Project Operator can conduct at any time a quantification of CO_2 stored in project trees. If that quantification yields more credits than were issued during the project's 25-year project duration (due to additional growth after 25-years or the planting of replacement trees), the Project Operator can request issuance of those additional credits.

9. Quantification of Carbon and Co-Benefits for Credits

The Registry will issue City Forest 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 run-off reduction, energy savings, and air quality.

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, "Verification for Tree Planting Projects." 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 for both the Single Tree Method and the Tree Canopy Method, and for the issuance of Forward Credits. App. C also contains requirements 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.
- 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 Preservation Projects

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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.
Project Implementation Agreement with the Registry	Once, within one year of Project Commencement	Agreement between Project Operator and Registry
Signed Declaration of Land Ownership or Permission	With Project Implementation Agreement, or upon any change in ownership or permission	Declaration of Project Operator on Ownership of Land or Permission
Signed Declaration of Compliance	With Project Implementation Agreement	Declaration 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.

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Appendix B

Quantification Methods for Tree Planting Projects

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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 examples.

The Registry will provide spreadsheet tools that will make using these methods as easy as possible. Users will 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.

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

Overview of Quantification in Planting Projects

Project Operators will select one of two different methods for quantifying CO_2 stored in their project trees:

- Single Tree Method (where planted trees are dispersed or scattered among many existing trees, such as street or yard tree plantings) or
- 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 Canopy Method requires tracking of changes in the project's overall tree canopy area using data and the i-Tree tool.

A Project Operator thus selects the appropriate quantification method – either Single Tree or Canopy. He or she then applies that method at two different time periods – during the issuance of Forward Credits and at the end of a project. The Tools that pertain to these two time periods are the Forward Credit Quantification Tool and the Final Quantification Tool.

Thus there are four different quantification Tools:

- Single Tree Forward Credit Quantification
- Single Tree Final Quantification
- Canopy Forward Credit Quantification
- Canopy Final Quantification

Let's illustrate this with an example. Let's assume that a Project Operator seeks Forward Credits (to receive credits earlier in a project) using the Single Tree Method. The Project Operator will use the Single Tree Forward Credit Quantification Tool.

This Tool enables the Project Operator to calculate projected carbon stored in his or her project using planting data. Forward credits can be issued at three times – after planting, after year 3, and after Year 5. The Single Tree Quantification method for those Forward Credits involves projecting the carbon storage of project trees, and adjusting for mortality at each of the three times that forward credits are requested.

The Project Operator then conducts a Single Tree Final Quantification at the end of the 25-year project. This determines the amount of actual CO_2 stored and the final credits earned. The number of Forward Credits issued are deducted from the final number of credits, and the Registry issues the excess credits to the Project Operator.

This Appendix B contains detailed examples of three of the four Tools - Single Tree Forward Credit Quantification, Single Tree Final Quantification, and Canopy Final Quantification, with associated spreadsheet tables and calculations. The fourth Tool – the Canopy Forward Credit Quantification Tool – is available upon request,

Before describing those Tools in detail, here is a summary of the steps used in each of the three different processes.

Summary of Quantification Steps in Three Tools

This section summarizes the steps in three Tools used to quantify carbon storage in tree planting projects.

Steps for Single Tree Forward Credit Quantification

1) For each planting site, collect this information
    a. Unique site number
    b. Unique tree number (may be several tree numbers at same site if remove & replace)
        i. Tree species planted
        ii. Date planted
    c. Tree number removed
        i. Date removed
    d. GPS coordinates (lat/long)
    e. Notes
2) Determine sample size using Sample Size Calculator
    a. Using your complete list of site numbers, configure it as a list of random numbers that do not repeat and use Excel functions to select random sample of sites to visit (see below)
3) Project Operator visits each sample site
    a. Confirm accuracy of
        i. Site number
        ii. Tree number
        iii. Species identification
    b. Record status

i. Live
    1. Original
    2. Replacement #1
    3. Replacement #2

ii. Standing dead

iii. Vacant
    1. Removal date #1 if known
    2. Removal date #2 if known

c. Photograph tree site
    i. Include time stamp and GPS coordinates
    ii. Capture tree size and condition in 2 images at approximately 90°
    iii. If site is vacant, place orange reflective rod (4 ft long) where tree was planted to show site location.

4) Calculate percentage of sample trees that are live
    a. Divide number of live trees recorded by total sites sampled (ex: 70/100 = 0.70)

5) Multiple this number by the forecasted CO_2 credits in spreadsheet to adjust forward credits for mortality.

Steps for the Single Tree Final Quantification Method

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

Steps for the Canopy Final Quantification 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.

Quantification Methods and Examples

Single Tree Forward Credit Quantification

The steps above summarized the quantification processes for the three methods described in this Appendix. Below is a detailed walk-through of the Single Tree Forward Credit Quantification. Project operators will use this process and Tool to request Forward Credits in projects where trees are not planted contiguously.

The Registry will provide the Tool that contains look-up tables and calculations built in to the spreadsheet so that projects can enter their project data and then walk through the sheets to quantify CO_2 and co-benefits.

Overview

Forward Crediting Method

The analyst can use this method to calculate the amount of CO_2 (in metric tonnes, t) stored by live project trees after 25 years for forward crediting. Forward Credits can be issued at three points in time – within one year after planting, after year 3, and after year 5. Basic data on all trees need to be collected at the time of planting. Then, when a user wishes to seek Forward Credits at one of the three points in time above, they will use this tool to select a random sample of sites for collection and entry of a few additional pieces of data. Sampling reduces costs of monitoring and verification. This tool then calculates CO_2 stored, co-benefits, and the number of Forward Credits that may be issued. Users will submit this spreadsheet to the Registry with current images of sample tree sites so the Registry can verify the process and sampled data.

Steps

1) Plant project trees and collect the following data on each planted tree using the data collection table included in this workbook: species, site id#, tree id# and location (latitude and longitude). We use the term "site" instead of "tree" because some planted trees may no longer be present in the sites where they were planted.

2) Compile data on the numbers of trees planted by species from the Data Collection table and use this information to fill in the Planting List (Table 1).

3) The Sample Size Calculator will automatically determine the number of sites to sample (Table 3).

4) Create a random sample of sites to visit. For further instructions see the Random Sampling sheet. Note that if you choose to collect data at more than one of the allowed time steps (immediately after planting, at year 3, and at year 5) DIFFERENT random samples must be drawn at each of those times to avoid any sampling bias.

5) Collect data at each sample site using the Data Collection table included in this workbook. For further instructions see the Data Collection sheet.

6) Enter data on the number of live trees and vacant sites from the Data Collection table into Table 5 on the Sample Data sheet.

7) Forward Credits will be automatically calculated in Table 6.

8) Table 7 automatically infers the amount of CO_2 stored after 25 years from the sample to the population of live trees.

9) For planning purposes only, users can enter a low and high price of CO_2 ($ per t) in Table 8. Table 9 incorporates error estimates of ±15% to calculate low and high amounts of CO_2 stored.

10) Table 10 automatically provides estimates of co-benefits for live trees after 25 years in Resource Units (e.g., kWh) per year and $ per year.

Data Collection

Directions

Create a data sheet with the same fields seen in the example below.

At the time of data collection soon after planting, record the following information:

- Date of data collection.
- Names of the crew that collected that data.

At the time of data collection soon after planting record the following information on each tree:

- Date planted
- Site Id#, a unique number assigned to each spot a tree is planted at.
- Species name (botanical name)
- Tree Id#, the unique number that conincides with each tree that was planted at the site. When each tree has just been planted, and there are not any dead or missing trees, the tree id#s will all be the same as the site#s. As trees get replaced, the list of tree id#s will increase. In the example below, site# 1 has a replacement tree planted in it, therefore what was originally tree #1 is now tree #4. If tree #4 is the next one at the project that gets replaced, that new tree will then be tree# 5.
- latitude and longitude or x and y coordinates of where each tree is located. These data are used to accurately locate the site for remeasurement.

To request Forward Credits, draw a random sample and record these additional data on each tree site sampled.

- If the tree is alive, record if it is the original one planted (original) or a replacement (replace#1, replace#2).
- Record if the tree is dead (standing) or missing (vacant site).
- image#1, the unique number for the first image of this site.
- image#2, the unique number for the second image of this site taken at 90 degrees to the first.
- Date removed, the date when the tree was removed.
- Date replaced, the date when the replacement tree was planted.
- Notes, information concerning tree status, health, etc.

During subsequent field sampling sessions you may find it helpful to take a copy of your original data sheets along for reference when attempting to locate each tree.

Example Data Collection Table

Data Collection Date: 04/24/2017 Crew: Julie and Ed

date planted	site id#	species	tree id #	x coord	y coord	live (orig/replace #1/replace #2)	standing dead or vacant site	image#1	image#2	date removed	date replaced	notes
9/15/2016	1	Celtis reticulata	4	33.968715	-117.343649	R#1		1	2	3/1/2017	4/5/2017	Original tree (#1) removed & replaced (#4)
9/15/2016	2	Pistacia chinensis	2	32.967521	-117.263458		vacant	3	4	2/21/2017		Dead tree (#2) removed , not replaced
9/15/2016	3	Platanus racemosa	3	32.873459	-116.839654	Orig		5	6			Originally planted tree (#3) alive

Planting List

Directions

1) In Table 1 record the number of sites planted for each tree species.
2) If species are not listed, add them to the bottom of Table 1.

Table 1. Planting List

ScientificName	CommonName	Tree-Type Abbreviation	No. Sites Planted
Acacia baileyana	Bailey acacia	BES	
Acacia melanoxylon	black acacia	BEL	
Acacia species	acacia	BEM	
Acer buergerianum	trident maple	BDS	
Acer negundo	boxelder	BDL	
Acer palmatum	Japanese maple	BDS	16
Acer platanoides	Norway maple	BDL	
Acer rubrum	red maple	BDL	33
Acer saccharinum	silver maple	BDL	
Acer species	maple	BDL	
Acer tataricum subsp ginnala	Amur maple	BDS	
Acer x freemanii	Freeman maple	BDL	
Aesculus californica	California buckeye	BDS	
Aesculus carnea	red horsechestunt	BDM	
Aesculus pavia	red buckeye	BDS	
Ailanthus altissima	tree of heaven	BDM	
Albizia julibrissin	mimosa	BDS	
Alnus cordata	Italian alder	BDM	
Alnus rhombifolia	white alder	BDL	
Araucaria species	araucaria	BEL	
Arbutus unedo	strawberry tree	BES	
Betula pendula	European white birch	BDM	
Betula species	birch	BDM	
Brachychiton populneus	kurrajong	BEM	
Callistemon citrinus	lemon bottlebrush	BES	
Callistemon viminalis	weeping bottlebrush	BES	
Calocedrus decurrens	incense cedar	CEL	
Carpinus betulus 'Fastigiata'	hornbeam 'fastigiata'	BDM	
Carpinus caroliniana	American hornbeam	BDM	
Carya illinoinensis	pecan	BDL	
Casuarina equisetifolia	Australian pine	BEL	
Catalpa speciosa	northern catalpa	BDL	
Cedrus atlantica	Atlas cedar	CEL	
Cedrus deodara	deodar cedar	CEL	
Celtis australis	European hackberry	BDL	
Celtis occidentalis	northern hackberry	BDL	
Celtis reticulata	western hackberry	BDS	
Celtis sinensis	Chinese hackberry	BDL	41
Ceratonia siliqua	algarrobo Europeo	BEM	

Table 2. Summary of Planting Sites

Tree-Type	Tree-Type Abbreviation	No. Sites Planted
Brdlf Decid Large (>50 ft)	BDL	140
Brdlf Decid Med (30-50 ft)	BDM	94
Brdlf Decid Small (<30 ft)	BDS	16
Brdlf Evgrn Large (>50 ft)	BEL	0
Brdlf Evgrn Med (30-50 ft)	BEM	0
Brdlf Evgrn Small (<30 ft)	BES	0
Conif Evgrn Large (>50 ft)	CEL	0
Conif Evgrn Med (30-50 ft)	CEM	0
Conif Evgrn Small (<30 ft)	CES	0
	Total Sites Planted	250

Sample Size Calculator

Table 3. Sample Size Calculator

Description		Value
1)	Margin of Error (15% required)	15%
2)	Confidence level (95% required)	95%
3)	Total number of project sites	250
4)	Mean stored CO_2 per tree (kg)	1128
5)	Standard deviation of stored CO_2 (kg)	642
6)	Expected proportion of tree survival (75% required)	75%
	Calculated sample size	87

Use the Sample Size Calculator that we provide to determine the number of sites to sample. We use the term "site" instead of "tree" because some planted trees may no longer be present in the sites where they were planted.

Directions

1) Margin of error, the default value of 15% is used.
2) Confidence level, the default value of 95% is used.
3) The total number of original sites is automatically filled in from the Planting List tab.
4) Mean stored CO_2 for all tree types 25 years after planting is automatically filled in from Table 4 below.
5) Standard deviation of the average CO_2 stored for all tree types 25 years after planting is automatically filled in from the Table 4.
6) Expected proportion of tree survival – for sampling purposes we conservatively estimate that 75% of the planted trees are expected to survive. This value is used as the default in the Sample Size Calculator.

Table 4. Stored CO_2 (kg) by tree type for years after planting in Inland Valley climate zone.

Age	BDL	BDM	BDS	BEL	BEM	BES	CEL	CEM	CES	Avg.	Std. Dev.
5	104	251	78	59	24	13	39	13	47		
10	434	725	230	239	133	60	259	203	167		
15	1,011	1,232	395	570	315	150	761	964	315		
20	1,836	1,735	560	1,062	550	288	1,623	2,021	475		
25	**2,894**	**2,223**	**721**	**1,718**	**824**	**478**	**2,912**	**2,162**	**640**	**1,128**	**642**
30	4,167	2,695	877	2,536	1,128	725	4,688	2,162	807		
35	5,631	3,150	1,028	3,505	1,454	1,031	7,006	2,162	974		
40	7,259	3,589	1,174	4,614	1,799	1,400	9,918	2,162	974		

Random Sampling

Use this to create a random list of site IDs to sample.

Random List of Sites
124
129
16
165
194
5
30
182
207

Directions

1) Replace the XXXX in the following formula with the total number of sites, =RANDBETWEEN(1,XXXX). Copy and paste that formula into cell B5.
2) Replace the XXXX in the following formula with the total number of sites, =LARGE(ROW($1:$XXXX)*NOT(COUNTIF(B5:B5,ROW($1:$XXXX))),RANDBETWEEN(1,(XXXX+2-1)-ROW(B5)))
3) Copy and paste that formula into cell B6. You will get a #NUM! error in that cell. Double click that cell and then press CTRL+SHIFT+ENTER to enter this as an array formula.
4) Copy cell B6 down for as many rows as you are required to sample, the resulting values should all be unique.
5) Starting in cell B5 you have a list of random site numbers where you will collect data.
6) Note that DIFFERENT random samples must be drawn each time crediting is sought to avoid any sampling bias.

Sample Data

Dirtections

1) In Table 5 Cols. D-F enter the number of live trees sampled (originally planted, 1st and 2nd replacements) by tree type.
2) In Table 5 Cols. H-I enter the number of vacant sites sampled (original tree not replaced, 1st replacement removed and not replaced, 2nd replacement removed and not replaced) by tree type.

Table 5. Sample Data on Tree Numbers

Sample Data	Number of Sites Originially Planted	Sampled - No. Live Original Planting	Sampled - No. Live 1st Replacements	Sampled - No. Live 2nd Replacements	Total Sites Sampled - Live Trees	Sampled Dead - Original Planting Not Replaced	Sampled - Dead - 1st Replacements, Not Replaced	Sampled - Dead - 2nd Replacements, Not Replaced	Total Sites Sampled - Vacant / Dead Trees	Total Sites Sampled	Original Planting Survival (%)	Current Survival w/ Replacements (%)	Extrapolation Factor	Total Number Live Trees Inferred from Sample
Brdlf Decid Large (>50 ft)	140	34	4	1	39	12	1	0	13	52	65	75	2.69	105
Brdlf Decid Med (30-50 ft)	94	23	1	1	25	12	3	0	15	40	58	63	2.35	59
Brdlf Decid Small (<30 ft)	16	4	1	0	5	3	0	0	3	8	50	63	2.00	10
Brdlf Evgrn Large (>50 ft)	0				0				0	0	0	0	0	0
Brdlf Evgrn Med (30-50 ft)	0				0				0	0	0	0	0	0
Brdlf Evgrn Small (<30 ft)	0				0				0	0	0	0	0	0
Conif Evgrn Large (>50 ft)	0				0				0	0	0	0	0	0
Conif Evgrn Med (30-50 ft)	0				0				0	0	0	0	0	0
Conif Evgrn Small (<30 ft)	0				0				0	0	0	0	0	0
	250	61	6	2	69	27	4	0	31	100	61	69		174

Forward Credits

Directions

Using the information you provide and background data, the tool calculates the amount of credits that could be issued at years 1 (10%), 3 (40%) and 5 (30%) after planting. A mortality deduction (% loss) is applied to account for tree losses based on sampling results.

Table 6. Forward credits are based on 10%, 40% and 30% at Years 1, 3 and 5 after planting, respectively, of the projected CO2 stored by live trees 25-years after planting. This value accounts for tree losses based on sampling results.

						10%	40%	30%
	No. Sites Planted	**No. Live Trees**	**Mortality Deduction (%)**	**25-yr CO_2 stored (kg/tree)**	**Tot. 25-yr CO_2 stored (t)**	**10% CO_2 (t)**	**40% CO_2 (t)**	**30% CO_2 (t)**
BDL	140	105	0.25	2894.27	303.9	30.39	121.56	91.17
BDM	94	59	0.38	2223.15	130.6	13.06	52.24	39.18
BDS	16	10	0.38	720.75	7.2	0.72	2.88	2.16
BEL	0	0	0	0.00	0.0	0.00	0.00	0.00
BEM	0	0	0	0.00	0.0	0.00	0.00	0.00
BES	0	0	0	0.00	0.0	0.00	0.00	0.00
CEL	0	0	0	0.00	0.0	0.00	0.00	0.00
CEM	0	0	0	0.00	0.0	0.00	0.00	0.00
CES	0	0	0	0.00	0.0	0.00	0.00	0.00
	250	174	0.31		441.7	44.17	176.69	132.51

Total CO_2

In Table 7 the tool infers the amount of CO_2 stored after 25 years from the sample to the population of live trees.

Table 7. Grand Total CO_2 Stored after 25 years (all live trees, includes tree losses)

Tree-Type	**No. Sites Planted**	**Extrap. Factor**	**Total Live (Original + Replaced Trees) Sampled**	**Total Number Live Trees Inferred from Sample**	**Sample CO_2 Tot. (kg)**	**Grand Total CO_2 (t)**
Brdlf Decid Large (>50 ft)	140	2.69	39	105	112,876.5	303.90
Brdlf Decid Med (30-50 ft)	94	2.35	25	59	55,578.7	130.61
Brdlf Decid Small (<30 ft)	16	2.00	5	10	3,603.7	7.21
Brdlf Evgrn Large (>50 ft)	0	0	0	0	0.00	0.00
Brdlf Evgrn Med (30-50 ft)	0	0	0	0	0.00	0.00
Brdlf Evgrn Small (<30 ft)	0	0	0	0	0.00	0.00
Conif Evgrn Large (>50 ft)	0	0	0	0	0.00	0.00
Conif Evgrn Med (30-50 ft)	0	0	0	0	0.00	0.00
Conif Evgrn Small (<30 ft)	0	0	0	0	0.00	0.00
	250		69	174	172,058.9	441.72

CO_2 Summary

Directions
In Table 8, enter the low and high price of CO_2 in $ per tonne (t).

This table incorporates error estimates of ±15% to the high and low estimates of the total CO2 (t) stored by the live tree population after 25 years. For planning purposes only, it calculates dollar values.

Table 8. CO_2 value

	CO_2 $ per tonne
Low	$20.00
High	$40.00

Table 9. Summary of CO_2 stored after 25 years (all live trees, includes tree losses)

Tree-Type	**Total CO_2 (t) at 25 years**	**Low $ value**	**High $ value**
Brdlf Decid	441.72	$8,834.31	$17,668.63
Brdlf Evgrn	0.00	$0.00	$0.00
Conif Evgrn	0.00	$0.00	$0.00
Total	441.72	$8,834.31	$17,668.63
	CO_2 (t)	**Total $**	**Total $**
Grand Total CO_2 (t) at 25 years:	441.72	$8,834.31	$17,668.63
High Est. with Error:	507.97	$10,159.46	$20,318.92
Low Est. with Error:	375.46	$7,509.17	$7,509.17
± 15% error = ± 10% formulaic ± 3% sampling ± 2% measurement			

Co-Benefits

Using the information you provide and background data, the tool provides estimates of co-benefits after 25 years in Resource Units per year and $ per year.

Table 10. Co-Benefits per year after 25 years (all live trees, includes tree losses)

Ecosystem Services	Res Units Totals	Res Unit/site	Total $	$/site
Rain Interception (m3/yr)	734.20	2.94	$1,512.86	$6.051
CO2 Avoided (t, $20/t/yr)	16.86	0.07	$337.17	$1.349
Air Quality (t/yr)				
O3	0.0998	0.0004	$1,100.35	$4.401
NOx	0.0244	0.0001	$686.65	$2.747
PM10	0.0517	0.0002	$1,072.53	$4.290
Net VOCs	0.0010	0.0000	$10.34	$0.041
Air Quality Total	0.1768	0.0007	$2,869.86	$11.48
Energy (kWh/yr & kBtu/yr)				
Cooling - Elec.	39,554.23	158.22	$4,612.02	$18.45
Heating - Nat. Gas	18,835.65	75.34	$234.40	$0.94
Energy Total ($/yr)			$4,846.42	$19.39
Grand Total ($/yr)			$9,566.31	$38.27

Single Tree Final Quantification

There are two different methods for quantifying carbon storage for progress credits 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.

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

Canopy Forward Credit Quantification Method

The Registry will provide this Tool and its instructions upon request.

Canopy Final Quantification 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

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 for Tree Planting Projects

Public Comment Version 4

October 2017

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Note that Verification requirements for Tree Preservation projects are contained in the Tree Preservation Protocol.

1. Verification per ISO 14064-3

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

- 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. The Registry will maintain its status as a non-profit organization, and will be independent of specific project activities.
- A trained peer reviewer will audit the Registry's verification, utilizing standards to be adopted by the Registry.
- Registry verification with peer review is justified by the processes and standard set forth below, and by the fact that urban forest planting projects, unlike many other types of carbon offset projects, will be conducted in urban areas, by definition. The trees planted in urban forest projects will be visible to virtually any resident of that urban area, and to anyone who cares to examine project trees.
- The Registry will maintain independence from the activities of projects, will conduct all verification work with ethical conduct and a fair presentation of its verification work, will treat all projects equally with regard to verification, and will conduct its verification work with skill, diligence, and competence.
- The Registry requires a reasonable level of assurance in the accuracy the asserted GHG removals to a reasonable level.

- The verification items identified in Tables C.1, C.2, and C.3 are all material elements, and any asserted GHG removals must be free of errors, misstatements, or omissions regarding those elements.
- The Registry will verify all sampled trees for issuance of forward credits and for issuance of any other credits under both the Single Tree Method and the Tree Canopy Method.
- The Registry will record, store, and track all quantification and verification data and either display it for public review or make it available for public review upon request.
- The Registry will develop a risk assessment standard to provide a cross-check on data collection and review.
- The Registry will adopt a process for follow-up and maintenance for consistency and continuity.

2. Verification for Issuance of Forward Credits

Table C.1 displays the various verification requirements to be performed upon request by a Project Operator for forward credits under Section 2.3.B of this protocol. Further guidance on elements in Table C.1 follow in Section 6.

Table C.1

Item	Elements to Verify	Protocol Section	How
1.	PO Identity	1.1	State/local records
2.	PIA	1.2	Signed/received
3.	Location	1.3	Mapping/location data
4.	Right to Receive Credits	1.4	Signed Decl. of Ownership/Permiss.

5.	Commencement	5	Proj. Documentation
6.	Proj Documentation	4	Check
7.	Proj Duration	3	Signed PIA: for all above: Signed Decl. of Compliance
8.	Additionality		Registry Program
	100% Forest Buffer Pool	2.1	
	Performance Standard Baseline	2.2	
	Legal requirements Test	2.3	Check PIA and Ords; Decl. of Compliance
9.	PO's Forward Credit Mortality and Verif. Assessment:	6.2, 9, App. B	
	1. Accuracy of Process and Documents:		Check approp. Quant Tool
	a. Sample Size Calculation		Same
	b. Randomization of Sample		Same
	c. Calculations		Same
	d. Integrity of Spreadsheet		Same
	2. Field Data and Inputs into Spreadsheets:		
	a. Data from sampled trees		Geo-coded Photos of Sample Trees
	b. Data Input accuracy		Check inputs
	PO's Report	App. A	Check
	Reversals	7	PIA, Decl. of Compliance, PO's Report, sample data
	Buffer Pool Contributions	7	Confirm Transfer

3. Verification for Issuance of Credits Using the Single Tree Method

Table C.2 displays the various verification requirements to be performed upon request by a Project Operator for credits using the Single Tree quantification method under Appendix B on Quantification to this protocol.

Table C.2

Item	**Elements to Verify**	**Protocol Section**	**How**
1.	PO Identity	1.1	State/local records
2.	PIA	1.2	Signed/received
3.	Location	1.3	Mapping/location data
4.	Right to Receive Credits	1.4	Signed Decl. of Ownership/Permiss.
5.	Commencement	5	Proj. Documentation
6.	Proj Documentation	4	Check
7.	Proj Duration	3	Signed PIA: for all above: Signed Decl. of Compliance
8.	Additionality		Registry Program
	100% Forest Buffer Pool	2.1	
	Performance Standard Baseline	2.2	
	Legal requirements Test	2.3	Check PIA and Ords; Decl. of Compliance

9.	PO's Single Tree Quant Tool Spreadsheet:	9 and App. B	
	3. Accuracy of Process and Documents:		Check approp. Quant Tool
	e. Sample Size Calculation		Same
	f. Randomization of Sample		Same
	g. Calculations		Same
	h. Integrity of Spreadsheet		Same
4.	5. Field Data and Inputs into Spreadsheets:		
c.	d. Data from sampled trees		Geo-coded Photos of Sample Trees
e.	f. Data Input accuracy		Check inputs
	PO's Report	App. A	Check
	Reversals	7	PIA, Decl. of Compliance,PO's Report, sample data
	Buffer Pool Contributions	7	Confirm Transfer

4. Verification for Issuance of Credits Using the Tree Canopy Method

Table C.3 displays the various verification requirements to be performed upon request by a Project Operator for credits using the Tree Canopy quantification method under Appendix B on Quantification to this protocol. These credits may be progress credits or progress credits requested at the end of a project where forward credits were issued. Further guidance on elements in Table C.3 follow in Section 6.

Table C.3

Item	**Elements to Verify**	**Protocol Section**	**How**
1.	PO Identity	1.1	State/local records
2.	PIA	1.2	Signed/received
3.	Location	1.3	Mapping/location data
4.	Right to Receive Credits	1.4	Signed Decl. of Ownership/Permiss.
5.	Commencement	5	Proj. Documentation
6.	Proj Documentation	4	Check
7.	Proj Duration	3	Signed PIA: for all above: Signed Decl. of Compliance
8.	Additionality		Registry Program
	100% Forest Buffer Pool	2.1	
	Performance Standard Baseline	2.2	
	Legal requirements Test	2.3	Check PIA and Ords; Decl. of Compliance
9.	PO's Canopy Quant Tool Spreadsheet:	9 and App. B, C	
	6. Accuracy of Process and Documents:		Check approp. Quant Tool
	a. Calculations		Same
	b. Integrity of Spreadsheet		Same
			Same

	7. Field Data and Inputs into Spreadsheets:		
	g. iTree Canopy File, locations used to calculate canopy area		PO submits iTree Canopy file and Registry independently estimates canopy area for same project area, using subsample points to assess any interpreter error
	h. Data Input accuracy		
	PO's Report	App. A	Check
	Reversals	7	PIA, Decl. of Compliance, PO's Report, sample data
	Credit Hold-backs and Buffer Pool Contributions	7	Confirm Calcs in Tool and Transfer to Buffer Pool

5. Guidance on Specific Elements of Verification

Although the Registry reviews eligibility criteria upon initial application, this early review is not a verification review and does not suffice for issuance of credits. The following gives guidance for selected eligibility criteria.

5.1 Location

Projects must occur within the locations specified in Section 1.3 of the Protocol. Verification can include review the PO's designation of parcel numbers, addresses, or other indications of property location with reference to maps, KLM files, images from Google Earth or other reliable imaging sources.

5.2 Right to Receive Credits

Verification includes review of the Signed Affidavit of Ownership and Right to Receive Credits, together with any available ownership documents, including written agreements regarding ownership or right to receive credits. Verification entails a risk-based review that requires further review in any cases of lack of clarity or detail.

5.3 Project Commencement

Verification includes confirmation of the commencement date in the initial application, and in the Registry's database, plus confirmation that the commencement date meets the requirements of Section 5 of the Protocol.

5.4 Additionality

Verification requires confirmation of the existence of the Forest Buffer Pool in a size sufficient to cover the GHG assertion being verified, review of the Performance Standard Method applied at the Registry level, and review of the PIA for inclusion of compliance with the Legal requirements Test and an affidavit of compliance with the PIA. Further review of local ordinances of laws may be required to give a reasonable assurance that this requirement has been met.

5.5

A critical component of verification includes review of the PO's spreadsheet document containing planting data and completion of other data required to complete the mortality assessment or quantification of CO_2.

Tables C.1, C.2, and C.3 set out the specific elements that must be reviewed to complete verification of those documents.

6. Completing Verification

A verification report must be completed in order for credits to be issued. That report must include:

- Findings of the verifier as to each element in Table C.1, C.2, and C.3.
- A verification statement that supports the GHG assertion contained in the PO's appropriate spreadsheet and that states the number of credits that can be issued, including vintages.
- A log of all verification activities and communications with the PO.

The Registry shall also conduct a risk assessment and follow-up review of all verification activity and document that review.