CITY FOREST CREDITS

Tree Planting Protocol

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Abbreviations and Acronyms

C	Carbon
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
Credit	A unit representing one metric ton of CO_2e
DBH	Diameter at Breast Height
GHG	Greenhouse gas
ICROA	International Carbon Reduction Offset Alliance
ISO	International Organization for Standardization
PIA	Project Implementation Agreement
PO	Project Operator
Registry	City Forest Credits/Urban Forest Carbon Registry

Introduction

This City Forest or 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 terms "city forests" or "urban forests."

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 in 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 of city forest carbon offset credits, called City Forest Carbon+ Credits™.

Contributions of City Forests to Carbon Storage, Energy Savings, Storm Water Reduction, Air Quality, and Climate Mitigation

City forests in the U.S. are estimated to store over 770 million metric tons of CO_2.[1] The co-benefits of urban forests include air quality improvements, energy savings from reduction of the urban heat island effect in hot weather and reduction of heating costs due to wind mitigation in cold weather, slope stability, bird and wildlife habitat, sound and visual buffering, public health improvements, crime reduction, 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]

[1] Nowak, D.J. and E.J. Greenfield. 2018. U.S. Urban Forest Statistics, Values, and Projections. J. For. 116, 164-177.

[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

Recently updated research has documented the magnitude of the contributions of city forests to climate mitigation. Annually, these trees produce a total of $18.3 billion in value related to 1) air pollution removal ($5.4 billion), 2) reduced building energy use ($5.4 billion), 3) carbon sequestration ($4.8 billion), and 4) avoided pollutant emissions ($2.7 billion).[4] See also McMichael, C., McPherson, M., and Nordman, A., *City Forests – Functions, Scale, and Values of Climate and other Benefits,* City Forest Credits White Paper. December 2018.

Loss of Tree Cover in Urban and Community Areas in the United States

The City Forest Credits White Paper also cites peer-reviewed research published in 2018 showing the significant decline in urban tree cover in the United States. Data for all states in the U.S. show a national loss of urban and community tree cover of 175,000 acres per year during the study years of 2009-2014. Urban and community areas in the U.S. lose an estimated 36,000,000 trees each year.[5]

The total land area of lost urban and community tree cover during the study period of five years amounts to 1,367 square miles – a land area equal to the combined land area of New York City, Atlanta, Philadelphia, Miami, Boston, Cleveland, Pittsburgh, St. Louis, Portland, OR, San Francisco, Seattle, and Boise.

Public funding of urban forests remains minimal.[6] Trees are a maintenance and liability expense for cities, and despite the nature of urban forests as public resources, city trees are not “booked” as an asset on cities’ balance sheets. Financial managers in cities see only the expense. And when those managers weigh the expense of trees that have no asset value against dire needs for human services, utility services, public safety, transit, homelessness, and refugee communities, the trees move to the bottom of the budget.

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[4] Nowak, David J. et al. 2018. U.S. Urban Forest Statistics, Values, and Projections, Journal of Forestry 116(2), 164-177

[5] Nowak, D.J. and E.J. Greenfield. 2018. Declining urban and community tree cover in the United States. Urban For. Urban Green. 32, 32-55.

[6] McDonald, R., L. Aljabar, C. Aubuchon, H.G. Birnbaum, C. Chandler, B. Toomey, J. Daley, W. Jimenez, E. Trieschman, J. Paque, and M. Zeiper. Funding Trees for Health: An Analysis of Finance and Policy Actions to Enable Tree Planting for Public Health. *Global Solutions White Paper*. The Nature Conservancy, 19 September, 2017. See https://www.nature.org/content/dam/tnc/nature/en/documents/Trees4Health_FINAL.pdf

The work of this Drafting Group and of City Forest Credits is focused on the United States. But tree canopy loss in urban areas and shortage of public funding are common to cities around the world. These needs are becoming apparent to international organizations and are partly responsible for new initiatives like Cities4Forests at the World Resources Institute.[7] City Forest Credits has received inquiries from urban forest stakeholders in Uganda, Peru, Australia, the United Kingdom, Belgium, West Africa, Canada, and others, expressing the same concerns of increasing temperatures, rain fall and storm events, loss of trees, and shortage of public funding. These stakeholders ask if carbon protocols could help them to recruit new funding from the sale of credits to support this public resource of city forests.

Adding context to both the value of urban forests around the world and their decline is the recent report from the Intergovernmental Panel on Climate Change.[8] Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate. In the words of the Panel:

> *Pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems (high confidence). These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options.*[9]

One element of mitigation cited by the IPCC is Carbon Dioxide Removal (CDR). City Forests can contribute significantly to CDR, in addition to delivering other climate benefits, as cited above and in the City Forest Credits White Paper.

Also recently released is the National Climate Assessment from the U.S. Global Change Research Program, a program that includes the work of ten governmental

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[7] See WRI's Letter of Support dated September 4, 2018 for request of City Forest Credits to ICROA to review City Forest Credits' protocols.

[8] IPCC, 2018: Summary for Policymakers. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp

[9] Ibid at 17

agencies.[10] The Assessment documents many aspects of climate change and its consequences. It discusses some types of mitigation and adaptation, stating:

> *While these adaptation and mitigation measures can help reduce damages in a number of sectors, this assessment shows that more immediate and substantial global greenhouse gas emissions reductions, as well as regional adaptation efforts, would be needed to avoid the most severe consequences in the long term. Mitigation and adaptation actions also present opportunities for additional benefits that are often more immediate and localized, such as improving local air quality and economies through investments in infrastructure.*[11]

The Drafting Group understood that city forests uniquely serve as a bridge connecting the global atmospheric benefit of carbon storage with co-benefits that deliver local resilience and climate mitigation to the large populations in our cities and towns. The Drafting Group was mindful of the strong policy reasons, based on the facts and research cited above and in the White Paper, in favor of developing carbon protocols for this valuable public resource of city forests, a resource that delivers multiple benefits relating directly to climate. The Drafting Group worked diligently to develop a planting protocol that would meet standards of bodies like the International Climate Reduction & Offset Alliance and also be feasible in the real world of urban forestry.

Prior Efforts at Urban Forest Carbon Protocols

In 2011, the State of California's Air Resources Board (ARB) adopted an urban forest carbon protocol.[12] Despite the efforts of that drafting group, the protocol was acknowledged to contain some flaws and also to be too costly and burdensome to be implemented. It has had no applicants.

In 2013, the State of California awarded a grant to the Climate Action Reserve to develop a more streamlined and feasible urban forest protocol. The Reserve did adopt a planting protocol and a canopy-related management protocol.[13] But those protocols also were complicated and too burdensome to be implemented, a concern expressed

[10] **Jay**, A., D.R. Reidmiller, C.W. Avery, D. Barrie, B.J. DeAngelo, A. Dave, M. Dzaugis, M. Kolian, K.L.M. Lewis, K. Reeves, and D. Winner, 2018: Overview. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA. doi: 10.7930/NCA4.2018.CH1

[11] Ibid in Summary of Findings, Actions to Reduce Risks

[12] https://www.arb.ca.gov/regact/2010/capandtrade10/copurbanforestfin.pdf

[13] http://www.climateactionreserve.org/how/protocols/urban-forest/

by some members of that work group. Those CAR protocols have had no applicants. The State of California ARB did not begin a review process for those CAR protocols for adoption.

Four members of our Drafting Group served on the work group for those urban forest protocols at the Climate Action Reserve in 2013-2014.[14] The lead scientist on our Drafting Group also led the science work for the 2013 CAR protocols and for the 2011 ARB protocol. Our Drafting Group had little desire to develop more protocols that no one would use.

Our Drafting Group was also aware of the perception that city forests lacked the scale of carbon storage to make those projects worth including in carbon crediting. The field of urban forestry in general has not done a good job of educating the larger national and international science and forestry communities on the climate values and the quantifiable ecosystem benefits of urban forests. A significant part of that failure is due to the persistent and pervasive lack of public or private funding for city forests.

But, as noted above and in the City Forest Credits White Paper, stakeholders in urban forestry have a much broader lens than carbon alone. Urban forest scientists and professionals have documented the many climate and other benefits of city forests, even if they have not disseminated that documentation as broadly as it could have been.[15]

Urban forest professionals are also acutely aware that almost 80% of the population worldwide lives in metropolitan areas or in cities and towns, and that urbanization is a significant demographic trend of the 21st century.[16] The climate, ecosystem, and social benefits of urban forests flow directly to the people and communities who live in cities and towns.

The City Forest Credits White Paper also describes some of the programs that are beginning under City Forest Credit's existing protocols. A program in Austin, TX has the potential to conduct riparian re-forestation along 900 miles of rivers and stream, almost 10,000 acres. An urban forest preservation program in King County (metropolitan Seattle) could generate credits on 1,500 acres of enormously valuable

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[14] http://www.climateactionreserve.org/how/protocols/urban-forest/

[15] See a recent article in Scientific American reporting on research on loss of tree cover in U.S. cities at https://www.scientificamerican.com/article/u-s-cities-lose-tree-cover-just-when-they-need-it-most/

[16] Nowak, D.J. and E.J. Greenfield. 2018. U.S. urban forest statistics, values, and projections. J. For. 116, 164-177.

urban forest, with quantified storm water, air quality, and energy savings benefits in the tens of millions of dollars.

Single projects in city forests will not generate the carbon storage of large forestry projects, particularly those in developing countries. But as the White Paper shows, city forest projects bring together carbon storage with the resilience and climate mitigation benefits of quantified energy savings, air quality improvements, and rainfall interception, together with many other as-yet-not-quantified benefits, such as bird and wildlife habitat, crime reduction, slope stability, and public health benefits. And these all flow directly to the communities living 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.[17]

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

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

To complicate matters, 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

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

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, enforceable, 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 City 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 small number of wood utilization projects, urban trees are not merchantable, are not harvested, and generate no revenue or profit.
- With the exception of recent plantings in California using funds from its Greenhouse Gas Reduction Fund, almost 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 virtually no harvests, revenues, or profits for those who preserve and grow the urban forest.

These three key attributes lead to the conclusion that city 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 city forest protocols that encouraged participation in city 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 and Projects

A Project requires at least one Project Operator ("PO"), an individual or an entity, who undertakes a Project, registers it with the registry of City Forest Credits (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

Project Areas must be located in parcels within or along the boundary of 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/geographies/reference-maps/2010/geo/2010-census-urban-areas.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. The boundary of land owned, designated, and used by a municipal or quasi-municipal entity such as a utility for source water or water shed protection;

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

In recognition of the urban-rural gradient and the strong public policy interest in preserving open space and forest land within and along that gradient, the Project Area may lie outside the boundary of one of A through E above. But any Project Area outside the boundary of A through E above must lie within or across parcels that constitute a sequence, chain, or progression of contiguously connected parcels. In addition, some part of the property line of one of those contiguously connected parcels must be coterminous with the boundary of one of A through E above.

2. 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.

3. City Forest Carbon+ Credits with Ex Post Performance Guarantee

Each credit issued under this Planting Protocol includes:

- CO_2e by city forest project trees over a 25-year period, based on tree survival, quantification, and verification at survival milestones, as set forth below and in Appendix B on Quantification;
- Quantified co-benefits from city forest project trees of rainfall interception, air quality improvements, energy savings, and avoided CO_2e, all expressed in Resource Units and dollar values;
- Other benefits from project trees that can include slope and soil stability, flood control, wildlife habitat (including birds and pollinators), human health, and, where relevant, social and environmental justice;
- An ACR or Verra credit as a performance guarantee, retired in the name of the Buyer upon issuance of any City Forest Carbon+ Credit.

The ACR or Verra credits will guarantee the performance of the City Forest Carbon+ Credit. Each ACR or Verra credit meets the required criteria of carbon reduction offsets as stated by ICROA:[18]

[18] See ICROA Offset Standard Review Criteria, Essential Criteria, Section 5 (2017) and ICROA's Code of Best Practice for Carbon Management Services, Technical Specification v.2.1 at Section 2.

- Unique
- Real
- Measurable
- Permanent
- Additional

The ACR or Verra credit retired with each City Forest Carbon+ Credit represents one ton of CO_2e removed from the atmosphere under accepted principles, including those promulgated by ICROA. The Buyer receives that offset as part of the City Forest Carbon+ Credit, which also represents one ton of CO_2e that will be removed from the atmosphere over the 25-year project duration, as well as quantified co-benefits representing quantified Resource Units and avoided costs. ICROA has approved ACR and Verra standards, so offsets from those standards will supply the Performance Guarantee.[19]

The precise processes for retiring ACR or Verra credits in the name of the Buyer upon issuance of City Forest Carbon+ Credits is set forth in Attachment 1.[20]

4. Additionality

The Registry ensures additionality through the following three requirements:

A. The Performance Guarantee consisting of an ACR or Verra credit retired for each City Forest Carbon+ Credit. The ACR or Verra credit has already met the additionality standard, represents one ton of CO_2e already removed from the atmosphere, and is retired under Section 3 above;

B. A Legal Requirements Test that declares city trees planted due to an enacted law or ordinance not eligible (Section 4.1); and

[19] If ICROA disapproves of any specific methodologies on ACR or Verra, City Forest Credits will not use credits issued under those methodologies.

[20] Further discussion of the facts, policies, and rationale for Drafting Group's development of this Performance Guarantee as related to permanence, timing of credit issuance, and additionality, can be found in Appendix D.

C. A performance standard baseline developed in adherence with the WRI GHG Protocol (see Appendix D).

4.1 Legal Requirements Test

Trees planted because they are required by an ordinance or law are not eligible.

5. Project Duration

Projects must submit Project Reports and annual reports to the Registry and must 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 11. The Registry ensures permanence through the Performance Guarantee of the ACR or Verra credit retired as part of each City Forest Carbon+ Credit.

6. 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.

7. Project Commencement

Projects commence upon approval of their application by the Registry. Appendix A sets forth documentation and reporting requirements and deadlines. Per Appendix A, initial project documentation is due within 6 months of commencement (i.e., within 6 months of approval of the application by the Registry).

Plantings prior to May 1, 2017 are not eligible, unless a project requests Early Action status and provides written documentation to the Registry that it conducted planting projects prior to May 1, 2017 with explicit reference to or under the guidance of a carbon protocol and with CO_2 storage as a significant part of the reason for the project. The Registry retains sole discretion to determine Early Action status.

8. Aggregation of Properties under a Project

A Project Operator may aggregate multiple properties under one project as follows:

A. The Project Operator may aggregate multiple properties in the same city or in multiple cities

B. The Project Operator may aggregate properties under public or private ownership under the same project

C. All aggregated properties must be within one county or be part of a program whose Project Operator is a state-authorized agency, planning authority, or other similar entity

D. The initial planting of trees for all aggregated properties must occur within the same 12-month period

E. The Project Operator must demonstrate compliance with all Protocol requirements for each property within an aggregated project

F. The Project Design Document must include all properties

G. The Project Operator must obtain written pre-approval from the Registry for aggregation before submitting an application for a project that aggregates multiple properties.

9. Issuance of Credits for Tree Planting Projects

The Registry will issue City Forest Carbon+ Credits™, representing a metric ton of carbon dioxide equivalent (CO_2e), bundled with the quantified co-benefits of rainfall interception, energy savings, and air quality.

The Registry will issue Credits to projects that comply with the requirements of this protocol, as follows (the ACR or Verra offset credit retired with each City Forest Carbon+ Credit provides ex post crediting standards in addition to the City Forest Carbon+ Credit):

A. After planting of project trees: 10% of projected total CO_2e stored by Year 26, minus a 20% mortality deduction, subject to quantification conducted under the Registry's quantification methodology and verified by an approved third-party verifier;

B. After Year 3: 40% of projected total CO_2e stored by Year 26, subject to data collection, sampling, deductions for tree mortality determined by sampled data, and quantification conducted under the Registry's quantification methodology and verified by an approved third-party verifier;

C. After year 5: 30% of projected total CO_2e stored by Year 26, subject to data collection, sampling, deductions for tree mortality determined by sampled data, and quantification conducted under the Registry's quantification methodology and verified by an approved third-party verifier;

D. At the end of the 25-year Project Duration, credits are calculated and issued as follows. The Registry has withheld 20% of projected credits (after mortality deductions) until the end of the project at Year 26. At that time, the Project Operator will conduct a Final Quantification of CO_2e and co-benefits. A third-party verifier must then approve the Project Operator's final GHG removal assertions. At that time, the Registry will issue "true-up" credits equaling the difference between credits already issued (which were based on projected CO_2e stored) and credits earned based on Final Quantification and verification of CO_2e stored;

E. 5% of total credits earned will be retained by the Registry for a Registry-wide Reversal Pool.

Projects can continue after Year 25, and earn credits, as provided in Section 11.

10. Reversals in Tree Planting Projects

Reversals can occur if there is a loss of stored carbon serving as the basis for credits for GHG emission mitigation after credits have been received by projects but before the end of the Project Duration commitment. (References in this section to "carbon" shall mean carbon serving as the basis for credits for GHG emission mitigation). A "Reversal" is loss of stored carbon such that the remaining stored carbon within the Project Area is less than the amount of stored carbon for which Registry credits have been issued. If the Project Operator or the Registry become aware of a potential Reversal, the Project Operator must estimate the amount of remaining carbon and report this estimate within 60 days of becoming aware of the loss.

The Registry shall determine, at its own discretion, whether a reversal was the result of intentional action or gross negligence by the Project Operator or property owner. If a Reversal was not the result of intentional action or gross negligence, the Registry will replace offsets invalidated by the Reversal with credits from the Registry's Reversal or Insurance Pool.

If the Registry determines that the Reversal was the result of an intentional action or gross negligence by the Project Operator, the Registry shall estimate the number of remaining creditable tonnes CO_2e using the quantification methods contained in this Protocol. The Registry shall notify the Project Operator of this count. If the Registry determines that more credits have been issued to the Project (counting both credits issued to the Project Operator and credits transferred to the Registry's offset insurance account), the Registry shall notify the Project Operator of this shortfall. The Project Operator shall be responsible for replacing the number of credits that have been issued but that are no longer supported by carbon storage within the Project Area. Within 60 days of being notified of the number of credits that it is obligated to replace, the Project Operator shall submit to the Registry a sufficient number of City Forest Carbon+ Credits to cover the shortfall. If the Project Operator is unable to obtain sufficient City Forest Carbon+ Credits, the Project Operator may pay the Registry $20 per tonne CO_2e of shortfall to satisfy the Project Operator's reversal obligation.

Quantifications of carbon stocks determined by the Registry shall be considered to be verified amounts under this section.

If the Project Operator disputes the Registry's reversal calculation, the Project Operator may, at its own expense, measure the remaining carbon stocks within the Project Area that may be more accurate than estimates made by the Registry. The Registry shall consider carbon stock counts submitted to it by the Project Operator, and if the Registry finds that the Project Operator's count is likely to be more accurate than the Registry's estimate, the Registry shall use the Project Operator's count of carbon stocks to determine the Project Operator's liability for replacing credits that are no longer supported by carbon storage within the Project Area.

If a Project has had its carbon stock go below the carbon stock necessary to support credits issued by the Registry, no further credits will be issued to the Project until the carbon stocks are above the amounts needed to support issued credits, including credits allocated to the Registry's Reversal account.

If a Project Operator fails to compensate for a reversal, that Operator may be barred, at the sole discretion of the Registry, from submitting applications to the Registry.

11. 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.

12. 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 outs methods for quantification. Each method requires certain steps, data samples from the Project Operator, data from imaging, data from look-up tables that are or will be provided, and calculations.

Appendix B also provides methods for calculating co-benefits, such as rainfall interception (one element of storm water run-off reduction), energy savings, and air quality. Appendix B contains a description of the quantification methods and the science used to develop those methods.

13. Verification

The Registry will issue credits only after a Project Operator submits a Project Report Requesting Verification and undergoes third-party verification by a verifier accredited 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 10.

The approved third-party verifier 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.

- App. C sets out standards for verification for project eligibility, quantification methods, and for the issuance of City Forest Carbon+ Credits. App. C also contains requirements for geocoded photographs, imaging, data, or similar landmarking that provides verification of the Project Operator's data on quantification.

- 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.

Attachment 1 – Processes for Retirement of ACR or Verra Performance Guarantee Credits with Issuance of City Forest Carbon+ Credits

When and How Performance Guarantee Credits Are Retired in the Name of a Buyer

- If Buyer is buying credits in Spot Purchases:
    - After the City Forest Credits Registry (the "Registry") has approved a Verification Report and been notified by a Project Operator that the Buyer has funded the City Forest Carbon+ Credits, the Registry will retire a Performance Guarantee Credit in the name of the Buyer for every City Forest Carbon+ Credit issued.
    - This obligation is contained in the Project Implementation Agreement between the Registry and the Project Operator
    - The Registry will give the Buyer view-only access to the Registry's Performance Guarantee ACR account so Buyer can confirm the supply of credits
- If the Buyer is making a Forward Purchase before Credits are issued:
    - Whenever the Project Operator notifies the Registry that the Buyer has funded the forward purchase of credits, the Registry retires Performance Guarantee Credits in the name of the Buyer. I.e., because Buyer has funded up-front, Buyer gets Performance Guarantee Credits retired up-front.
    - In these cases of forward purchases, the Registry will retire the same number of Performance Guarantee Credits as City Forest Carbon+ Credits that the Project Operator estimates it will earn, minus deductions

for the buffer pool and 20% mortality in a Credit Estimation Spreadsheet approved by the Registry.

- This obligation is contained in the Project Implementation Agreement between the Registry and the Project Operator
- The Registry issues City Forest Carbon+ Credits on its issuance schedule per Protocol. (Buyer has received retirement of ACR/Performance Guarantee Credits up-front.)
- The Registry will give Buyer access to its Performance Guarantee ACR account, so Buyer can confirm the Registry's supply of credits

Appendix A

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

Version 7

December 14, 2018

Urban Forest Carbon Registry, City Forest Credits, a 501(c)(3) non-profit organization
999 Third Ave. #4600
Seattle, WA 98104
info@cityforestcredits.org
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A.1 Documentation to Commence a Planting Project

Project Operators must provide the following documentation to City Forest Credits (the "Registry").

Document	When Submitted	Content Summary
Project Application	Once, at discretion of Project Operator. Projects commence upon approval of application by Registry	Project Operator, Location, Summary of Project
Project Design Document	Initial PDD submitted within 6 months of approval of application by Registry	Design of Project, Compliance with Eligibility Requirements.
Project Implementation Agreement with the Registry	Once, within 6 months of approval of application by Registry	Agreement between Project Operator and Registry
Signed Declaration of Land Ownership or Transfer from Owner to PO	With Project Implementation Agreement, or upon any change in ownership or permission	Declaration of Project Operator on Ownership of Land or Agreement from Owner to Transfer Credits

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 (approval of project by Registry)	Report confirming Project Operator, operational status, and any significant variations from eligibility, quantification, or Project Design Document
Request for Third-Party Verification and Credits	Always at end of Project Duration. Before that, required before verification or issuance of credits.	Can be PDD with updates on eligibility and quantification, as required by protocol.

A.3 Reporting During and at End of Project Duration

Projects must submit annual Status Reports for the Project Duration. During a project and at its end, the Project Operator may receive credits only after submitting a Request for Third-Party Verification and Credits. The Registry will issue credits per the provisions of the protocol.

The Request for Third-Party Verification and Credits must contain:

a. Any updated information or data on eligibility, and

b. Any updated quantification data required by the relevant protocol and appendices, including imaging of project trees or geo-coded photographs.

A.4 Record Keeping

Project Operators shall keep all documents and forms related to the project for a minimum of the Project Duration required by the protocol. If the Project seeks credits after the 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. 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

Version 7

December 2018

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This Appendix B on Quantification for Tree Planting Projects consists of two Parts. Part 1 contains a description of the science and methods underlying quantification of CO_2 and co-benefits in city trees.

Part 2 contains 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 principal author of this Appendix B on Quantification is Dr. E.G. McPherson. Dr. McPherson also led the science teams that developed quantification methods for the State of California Air Resources Board Urban Forest Carbon Protocol in 2011 and the Climate Action Reserve Urban Forest Protocols in 2014.

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

Part 1

Quantifying Carbon Dioxide Storage and Co-Benefits for Urban Tree Planting Projects

Introduction

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

Carbon Dioxide Storage

There are three different methods for quantifying carbon dioxide (CO2) storage in urban forest carbon projects:

- Single Tree Method - planted trees are scattered among many existing trees, as in street, yard and school plantings, individual trees are tracked and randomly sampled
- Tree Canopy Method for Park-like Projects- planted trees are relatively contiguous in park-like settings and change in canopy is tracked
- Tree Canopy Method for Riparian Projects – trees are planted very close together, significant mortality is expected, and change in canopy is tracked. The two main goals are to create a forest ecosystem and generate canopy.

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

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

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

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

Source Materials for Single Tree Method and Canopy for Park-like Projects Methods

Estimates of stored (amount accumulated over many years) and sequestered CO_2 (i.e., net amount stored by tree growth over one year) are based on the U.S. Forest Service's recently published technical manual and the extensive Urban Tree Database (UTD), which catalogs urban trees with their projected growth tailored to specific geographic regions (McPherson et al. 2016a, b). The products are a culmination of 14 years of work, analyzing more than 14,000 trees across the United States. Whereas prior growth models typically featured only a few species specific to a given city or region, the newly released database features 171 distinct species across 16 U.S. climate zones. The trees studied also spanned a range of ages with data collected from a consistent set of measurements. Advances in statistical modeling have given the projected growth dimensions a level of accuracy never before seen. Moving beyond just calculating a tree's diameter or age to determine expected growth, the research incorporates 365 sets of tree growth equations to project growth.

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

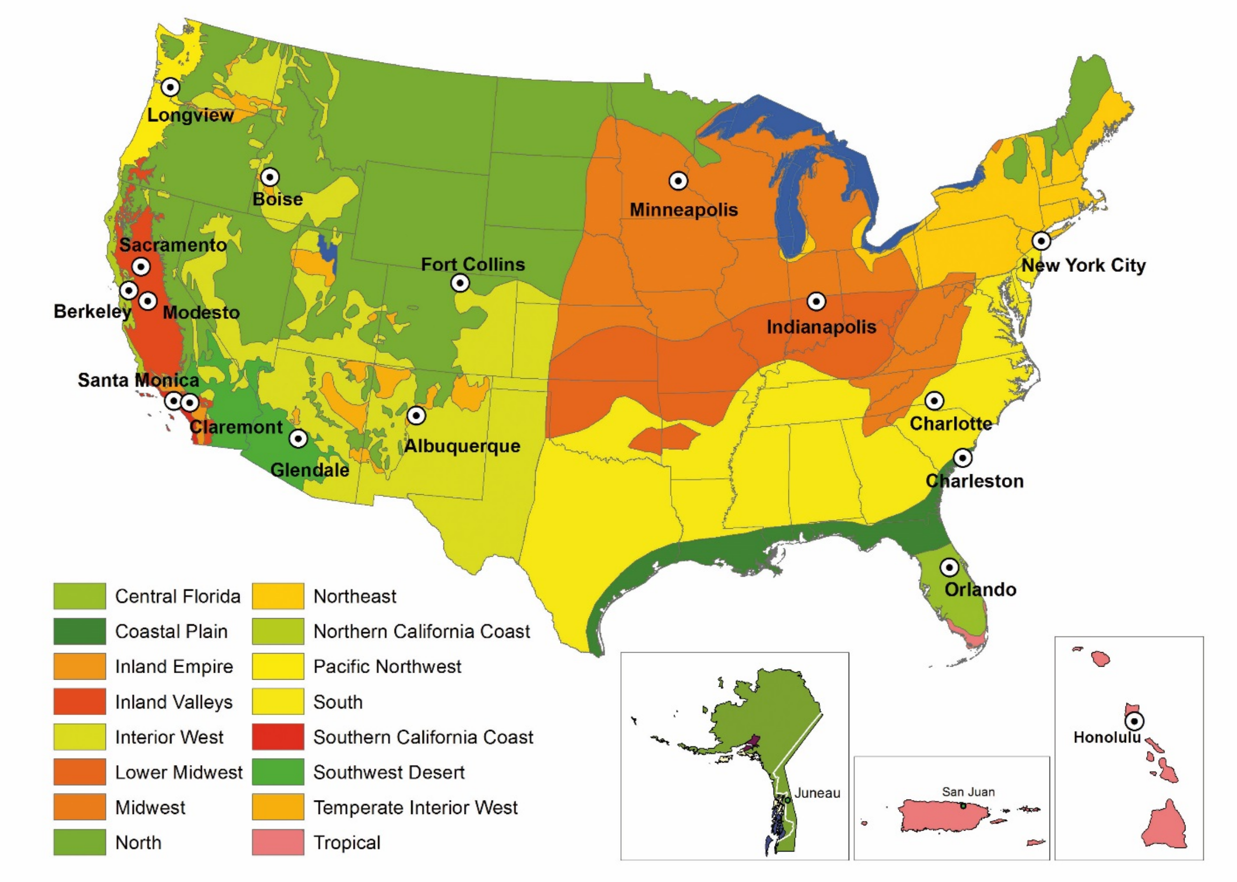

Fig. 1. Climate zones of the United States and Puerto Rico were aggregated from 45 Sunset climate zones into 16 zones. Each zone has a reference city where tree data were collected. Sacramento, California was added as a second reference city (with

Modesto) to the Inland Valleys zone. Zones for Alaska, Puerto Rico and Hawaii are shown in the insets (map courtesy of Pacific Southwest Research Station).

Species Assignment by Tree-Type

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

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

Tree-Type	Tree-Type Abbreviation	Species Assigned	DW Density	Biomass Equations
Brdlf Decid Large (>50 ft)	BDL	*Quercus phellos*	600	*Quercus macrocarpa* [1.]
Brdlf Decid Med (30-50 ft)	BDM	*Pyrus calleryana*	600	UGB [2.]
Brdlf Decid Small (<30 ft)	BDS	*Cornus florida*	545	UGB [2.]
Brdlf Evgrn Large (>50 ft)	BEL	*Quercus nigra*	797	UGB [2.]
Brdlf Evgrn Med (30-50 ft)	BEM	*Magnolia grandiflora*	523	UGB [2.]

Brdlf Evgrn Small (<30 ft)	BES	*Ilex opaca*	580	UGB [2.]
Conif Evgrn Large (>50 ft)	CEL	*Pinus taeda*	389	UGC [2.]
Conif Evgrn Med (30-50 ft)	CEM	*Juniperus virginiana*	393	UGC [2.]
Conif Evgrn Small (<30 ft)	CES	*Pinus contorta*	397	UGC [2.]
[1.] from Lefsky, M., & McHale, M.,2008.				
[2] from Aguaron, E., & McPherson, E. G., 2012				

Calculating Biomass and Carbon Dioxide Stored

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

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

These allometric equations yielded aboveground wood volume. Species-specific dry weight (DW) density factors (Table 1) were used to convert green volume into dry weight (7a). The urban general equations required looking up a dry weight density factor (in Jenkins et al. 2004 first, but if not available then the Global Wood Density Database). The amount of belowground biomass in roots of urban trees is not well researched. This work assumed that root biomass was 28% of total tree biomass

(Cairns et al., 1997; Husch et al., 2003; Wenger, 1984). Wood volume (dry weight) was converted to C by multiplying by the constant 0.50 (Leith, 1975), and C was converted to CO_2 by multiplying by 3.667.

Error Estimates and Limitations

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

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

Co-Benefit: Energy Savings

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

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

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

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

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

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

Error Estimates and Limitations

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

Co-Benefit: CO_2 Avoided

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

Error Estimates and Limitations

Estimates of avoided CO2 emissions have the same uncertainties that are associated with modeling effects of trees on building energy use. Also, utility-specific emission factors are changing as many utilities incorporate renewable fuels sources into their portfolios. Values reported in CFC tools may overestimate actual benefits in areas where emission factors have become lower.

Co-Benefit: Rainfall Interception

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

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

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

Error Estimates and Limitations

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

Co-Benefit: Air Quality

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

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

Error Estimates and Limitations

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

Conclusions

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

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Part 2

Overview of Quantification in Planting Projects

Project Operators will select one of three 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 plantings)
- Riparian Method (where trees are planted in riparian or similar areas, with the goal of generating canopy via closely-spaced planting and high expected mortality)

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.

The Riparian Method requires our scientists to apply GTR tables to data provided by the Project Operator on tree or forest type being planted, acres, climate zone, and other information. This is described in more detail in Attachment A at the end of this Appendix. Because quantification for this Riparian method depends on data specific to each project and application of GTR tables, we do not include examples or discussion in the body of this Appendix B.

A Project Operator thus selects the appropriate quantification method. He or she then applies that method at different time periods. The Tools used are the Initial Credit Quantification Tool, the Management Credit Quantification Tool, and the Final Quantification Tool.

Thus there are six quantification Tools, three for the Single Tree Method and three for the Canopy Method. The three Tools for each method are used near the beginning of a project, in the early years of a project, and at the end of the project in Year 25.

Single Tree Method:

- Single Tree Initial Credit Quantification
- Single Tree Management Credit Quantification
- Single Tree Final Quantification

Canopy Method:

- Canopy Initial Credit Quantification
- Canopy Management Credit Quantification
- Canopy Final Quantification

The Tool used depends on the time at which the Project Operator seeks Credits. The Registry will issue credits on the following tiered schedule per Section 9 of the Planting Protocol:

- After planting of project trees: 10% of projected total CO_2e stored by Year 26, minus a 20% mortality deduction and a 5% Buffer Pool deduction, subject to quantification conducted under the Registry's quantification methodology and verification by an approved third-party verifier;
- After Year 3: 40% of projected total CO_2e stored by Year 26, minus a 5% Buffer Pool deduction, subject to data collection, sampling, mortality data based on the sampled data, and quantification conducted under the Registry's quantification methodology and verification by an approved third-party verifier;
- After year 5: 30% of projected total CO_2e stored by Year 26, a 5% Buffer Pool deduction, subject to data collection, sampling, mortality data based on the sampled data, and quantification conducted under the Registry's

quantification methodology and verification by an approved third-party verifier;

- At the end of the 25-year Project Duration: all remaining credits issued after final quantification and verification of carbon stored, minus a 5% Buffer Pool deduction. Thus, at the end of Year 25, the Project Operator will conduct a final quantification with data collection, sampling, approval of the quantification methods by the Registry, and third-party verification. At that time, the Registry will issue “true-up” credits equaling the difference between credits already issued (which were based on projected CO_2e stored) and credits earned based on final quantification and verification of CO_2e stored;
- 5% of total credits earned and issued will be retained by the Registry for a Registry-wide Reversal Pool.

The Initial Credit Quantification Tool enables the Project Operator to calculate projected carbon stored in his or her project using planting data. The Tool applies a 20% mortality deduction as well as a 5% Buffer Pool deduction. The Project Operator can request to use an alternative value for the 20% mortality reduction. Justification for the value must be provided to the Registry based on historic mortality data for projects with similar species, planting stock, site quality and management regime.

The Management Credit Tool is used for Credits that can be issued in Year 4 and Year 6. The Management Credit Tool requires planting data, calculation of a sample number and sample sites, and then sampling of project trees to determine the presence of trees. This sampling produces a mortality adjustment that allows estimation of CO_2e storage after Years 4 and 6.

The Final Quantification Tool is used at the end of a project, in Year 25. It is the same basic Tool as the Credit Management Tool used in Years 4 and 6, except that it also requires measurement of dbh (diameter at breast height).

This Appendix B contains detailed examples of four of the six Tools - Single Tree Initial Credit Quantification Tool, Single Tree Management Credit Quantification Tool, Single Tree Final Quantification Tool, and Canopy Final Quantification Tool, with associated spreadsheet tables and calculations. The other Tools are available upon request.

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

Illustrative Summary of Quantification Steps in Four of the Tools

This section summarizes the steps in three Single Tree Tools used to quantify carbon storage in tree planting projects. These steps are set out in instructions on each sheet of the Quantification Spreadsheets. The steps will be much clearer to many readers when viewed within the spreadsheets rather than read here without tables, fields, and inputs. The next section of this Appendix – entitled Quantification Methods and Examples – gives screen shots of the spreadsheets with explanatory text.

Steps for Single Tree Initial 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) Photograph tree site or provide imaging of sufficient resolution to discern individual trees
   i. If using photographs, take photos at the four outer corners of each site, and also at 50 foot intervals on diagonal lines running between corners
   ii. Include time stamp and GPS coordinates
3) The Tool will deduct 20% for mortality and 5% for the program-wide Buffer Pool and then show projected CO2e storage and Credits
   a. The Project Operator can request to use an alternative value for the 20% mortality reduction. Justification for the value must be provided to the Registry based on historic mortality data for projects with similar species, planting stock, site quality and management regime.

Steps for the Single Tree Management Credit Quantification

1) Collect the planting data described in 1 above, specifically,
   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. GPS coordinates (lat/long)
   d. Notes
2) 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.

3) Randomly sample tree sites collecting data on species, status (alive, dead, removed, replaced).
4) With this sampled data, the Tool will then calculate projected CO2 storage and credits, and will set those out for Years 4 and 6, along with quantified Co-Benefits.

Steps for the Single Tree Final Quantification

1) Collect the planting data described in 1 above, or use the data already collected, specifically,
    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. GPS coordinates (lat/long)
    d. Notes
2) 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.
3) Randomly sample tree sites collecting data on species, status (alive, dead, removed, replaced), diameter at breast height (dbh) (to nearest inch), and photo of tree site (may be with or without the tree planted) with geocoded location and date.
4) Fill in the table provided showing the number of live trees sampled in each 1” dbh class by tree-type.

5) 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.
6) 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.
7) 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.
8) Fill in the table provided to incorporate error estimates of ±15% to CO_2 stored by the entire tree population.
9) 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

Data Collection for all Single Tree Quantification and Tools

At planting, Project Operators must collect the data listed below. Project Operators can update that data as the Project proceeds.

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 coincides 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
- 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.

Example Data Collection Table

Data Collection Date: 04/24/2018 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	1	33.96872	-117.344							
9/15/2016	2	Pistacia chinensis	2	32.96752	-117.263							
9/15/2016	3	Platanus racemosa	3	32.87346	-116.84							

Single Tree Initial Credit Quantification and Tool

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

The Registry will provide the Tools 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

Single Tree Projects Initial Credit Quantification Tool for the Southern California Coast Climate Zone
The analyst can use this method to calculate the amount of CO2 (in metric tonnes, t) estimated to be stored by live project trees after 25 years. Credits based on the estimated CO2 storage can be issued at three points in time – 10% within one year after planting, 40% after year 3, and 30% after year 5, minus 5% that will go into a program-wide buffer pool to insure against catastrophic loss of trees. At the end of the project, in year 25, Operators will receive credits for all CO2 stored, minus credits already issued. Project Operators will follow the Steps listed below to obtain an initial estimate that assumes 20% mortality. Basic tree planting data on all trees planted needs to be collected at the time of planting. Users will submit this spreadsheet to the Registry with other documentation so that the verifier can verify the planting before initial credits are issued. Sampled data will be used to obtain credits at subsequent points in time.

Steps
1) Compile data on the numbers of trees planted by species to fill in the Planting List (Table 1). When planting project trees collect the following data on each planted tree: 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) If the anticipted mortality rate in 25 years is NOT the default 20% of planted sites, the value is entered into row 6 on the Credits sheet. Justification for the value must be provided to the Registry based on historic mortality data for projects with similar species, planting stock, site quality and management regime.
3) Initial Credits will be automatically calculated and presented in Tables 3 and 4 (column H), incorporating anticipated tree losses and the 5% buffer pool deduction.
5) For planning purposes only, users can enter a low and high price of CO_2 ($ per t) in Table 5. Table 6 incorporates error estimates of ±15% to calculate low and high amounts of CO_2 stored.
6) Table 7 automatically provides estimates of co-benefits for live trees after 25 years in Resource Units (e.g., kWh) per year and $ per year.

Planting List

Enter the species and number planted as shown in Table 1 below.

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 decurrens	green acacia	BEM	
Acacia longifolia	Sydney golden wattle	BES	
Acacia melanoxylon	black acacia	BEL	
Acer palmatum	Japanese maple	BDS	
Acer rubrum	red maple	BDL	
Acer saccharinum	silver maple	BDL	
Acer species	maple	BDL	
Agonis flexuosa	peppermint tree; Australian willow myrtle	BES	
Albizia julibrissin	mimosa	BDS	16
Alnus cordata	Italian alder	BDM	
Alnus rhombifolia	white alder	BDL	
Annona cherimola	cherimoya	BES	
Araucaria bidwillii	bunya bunya	CEL	
Araucaria columnaris	coral reef araucaria	CEL	
Araucaria heterophylla	Norfolk Island pine	CEL	
Arbutus unedo	strawberry tree	BES	
Archontophoenix cunninghamian	king palm	PES	
Arecastrum romanzoffianum	queen palm	PES	
Bauhinia variegata	mountain ebony	BDS	
Betula pendula	European white birch	BDM	
Betula species	birch	BDM	94
Brachychiton populneus	kurrajong	BEM	
Brahea armata	Mexican blue palm	PES	
Brahea edulis	Guadalupe palm	PES	
Brahea species	brahea palm	PES	
Broadleaf Deciduous Large	broadleaf deciduous large	BDL	140
Broadleaf Deciduous Medium	broadleaf deciduous medium	BDM	
Broadleaf Deciduous Small	broadleaf deciduous small	BDS	
Broadleaf Evergreen Large	broadleaf evergreen large	BEL	
Broadleaf Evergreen Medium	broadleaf evergreen medium	BEM	
Broadleaf Evergreen Small	broadleaf evergreen small	BES	
Broussonetia papyrifera	paper mulberry	BDM	
Butia capitata	jelly palm	PES	
Calliandra tweedii	Trinidad flame bush	BES	
Callistemon citrinus	lemon bottlebrush	BES	
Callistemon viminalis	weeping bottlebrush	BES	
Calocedrus decurrens	incense cedar	CEL	

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

Initial Credits

This sheet calculates the Credits that can be issued in Year 1. It uses a default mortality of 20%. Project Operators may adjust that mortality deduction if they demonstrate to the Registry justification based on historic mortality data for projects with similar species, planting stock, site quality and management regime. Credits issued in Years 4 and 6 will depend on mortality based on sampling of trees in those years.

Directions

Enter the default 20% anticipted mortality rate (% of planted sites without trees in 25 years) into cell D6. Using the information you provide and background data, the tool calculates the amount of Credits that could be issued at years 1 (10%), 4 (40%) and 6 (30%) after planting. The mortality deductions (% loss) is applied to account for anticipated tree losses. A 5% buffer pool deduction is applied that will go into a program-wide pool to insure against catastrophic loss of trees.

Mortality Deduction (%): 20%

Table 3. Credits are based on 10%, 40% and 30% at Years 1, 4 and 6 after planting, respectively, of the projected CO2 stored by live trees 25-years after planting. These values account for anticipated tree losses and the 5% buffer pool deduction.

						10%	40%	30%
	No. Sites Planted	**No. Live Trees**	**Mortality Deduction (%)**	**25-yr CO_2 stored (kg/tree)**	**Tot. 25-yr CO_2 stored w/ losses and 5% deduction (t)**	**Initial CO_2 (t)**	**4 Years CO_2 (t)**	**6 Years CO_2 (t)**
BDL	140	112	0.20	1,794.13	190.9	19.09	76.36	57.27
BDM	94	75	0.20	629.52	45.0	4.50	17.99	13.49
BDS	16	13	0.20	422.19	5.1	0.51	2.05	1.54
BEL	0	0	0.20	0.00	0.0	0.00	0.00	0.00
BEM	0	0	0.20	0.00	0.0	0.00	0.00	0.00
BES	0	0	0.20	0.00	0.0	0.00	0.00	0.00
CEL	0	0	0.20	0.00	0.0	0.00	0.00	0.00
CEM	0	0	0.20	0.00	0.0	0.00	0.00	0.00
CES	0	0	0.20	0.00	0.0	0.00	0.00	0.00
	250	200		2,845.8	241.0	24.10	96.40	72.30

Total CO_2

In Table 4 the tool infers the amount of CO_2 stored after 25 years based on the anticipated population of live trees. Values in column H account for anticipated tree losses and the 5% buffer pool deduction.

Table 4. Grand Total CO_2 Stored after 25 years (all live trees, includes tree losses and buffer pool deduction)

Tree-Type	No. Sites Planted	Mortality Deduction (%)	Total Live Trees After Mortality	25-yr CO2 stored (kg/tree)	CO2 Tot. - No Deductions (t)	Grand Total CO2 w/ Deductions (t)
Brdlf Decid Large (>50 ft)	140	0.20	112	1,794.13	251.2	190.9
Brdlf Decid Med (30-50 ft)	94	0.20	75	629.52	59.2	45.0
Brdlf Decid Small (<30 ft)	16	0.20	13	422.19	6.8	5.1
Brdlf Evgrn Large (>50 ft)	0	0.20	0	0.00	0.0	0.0
Brdlf Evgrn Med (30-50 ft)	0	0.20	0	0.00	0.0	0.0
Brdlf Evgrn Small (<30 ft)	0	0.20	0	0.00	0.0	0.0
Conif Evgrn Large (>50 ft)	0	0.20	0	0.00	0.0	0.0
Conif Evgrn Med (30-50 ft)	0	0.20	0	0.00	0.0	0.0
Conif Evgrn Small (<30 ft)	0	0.20	0	0.00	0.0	0.0
	250		200	2,845.8	317.1	241.00

CO_2 Summary

Directions
In Table 5, enter the low and high price of CO_2 in $ per tonne (t).

Table 6 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 5. CO_2 value

	CO_2 $ per tonne
Low	$20.00
High	$40.00

Table 6. 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	241.00	$4,820.04	$9,640.09
Brdlf Evgrn	0.00	$0.00	$0.00
Conif Evgrn	0.00	$0.00	$0.00
Total	241.00	$4,820.04	$9,640.09
	CO_2 (t)	**Total $**	**Total $**
Grand Total CO_2 (t) at 25 years:	241.00	$4,820.04	$9,640.09
High Est. with Error:	277.15	$5,543.05	$11,086.10
Low Est. with Error:	204.85	$4,097.04	$4,097.04
± 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 Management Credit Quantification and Tool

Overview

Follow these directions, and also update the Data Collection Sheet that you completed at time of planting. See page 10 above.

Single Tree Project Management Credit Quantification Tool for the Tropical Climate Zone

The analyst can use this method to calculate the amount of CO2 (in metric tonnes, t) estimated to be stored by live project trees for Years 4 and 6 crediting. These credits are based on sample data that revise the estimated CO2 storage 25 years after planting from the anticipated value that assumed 20% mortality. Credits are issued at the rates of 40% in Year 4, and 30% in Year 6, minus 5% that will go into a program-wide buffer pool to insure against catastrophic loss of trees. This tool calculates benefits assuming trees are 25-years old with average dbh's of 20", 16" and 10" for large, medium and small tree-types, respectively.

To summarize the Tool briefly, Project Operators will sample trees from a random selection within the project area. They will record if each sample tree is alive, dead or missing. They will also photo-sample each sampling site and submit the images geocoded & time stamped. This tool then calculates CO2 stored, co-benefits, and the number of Credits that may be issued at Years 4 and 6. Users will submit this spreadsheet to the Registry with photo images so that the Registry can verify the process and sampled data. It is important to note that co-benefits to human health, satisfaction, attendance/absenteeism, and quality of life are not quantified by this tool, but can be compelling reasons for partners to invest in local projects.

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, after year 3, and after 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) 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.

Single Tree Projects Initial Credit Quantification Tool for the Southern California Coast Climate Zone

The analyst can use this method to calculate the amount of CO2 (in metric tonnes, t) estimated to be stored by live project trees after 25 years. Credits based on the estimated CO2 storage can be issued at three points in time – 10% within one year after planting, 40% after year 3, and 30% after year 5, minus 5% that will go into a program-wide buffer pool to insure against catastrophic loss of trees. At the end of the project, in year 25, Operators will receive credits for all CO2 stored, minus credits already issued.
Project Operators will follow the Steps listed below to obtain an initial estimate that assumes 20% mortality. Basic tree planting data on all trees planted needs to be collected at the time of planting. Users will submit this spreadsheet to the Registry with other documentation so that the verifier can verify the planting before initial credits are issued. Sampled data will be used to obtain credits at subsequent points in time.

Steps

1) Compile data on the numbers of trees planted by species to fill in the Planting List (Table 1). When planting project trees collect the following data on each planted tree: 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) If the anticipted mortality rate in 25 years is NOT the default 20% of planted sites, the value is entered into row 6 on the Credits sheet. Justification for the value must be provided to the Registry based on historic mortality data for projects with similar species, planting stock, site quality and management regime.

3) Initial Credits will be automatically calculated and presented in Tables 3 and 4 (column H), incorporating anticipated tree losses and the 5% buffer pool deduction.

5) For planning purposes only, users can enter a low and high price of CO_2 ($ per t) in Table 5. Table 6 incorporates error estimates of ±15% to calculate low and high amounts of CO_2 stored.

6) Table 7 automatically provides estimates of co-benefits for live trees after 25 years in Resource Units (e.g., kWh) per year and $ per year.

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 decurrens	green acacia	BEM	
Acacia longifolia	Sydney golden wattle	BES	
Acacia melanoxylon	black acacia	BEL	
Acer palmatum	Japanese maple	BDS	
Acer rubrum	red maple	BDL	
Acer saccharinum	silver maple	BDL	
Acer species	maple	BDL	
Agonis flexuosa	peppermint tree; Australian willow myrtle	BES	
Albizia julibrissin	mimosa	BDS	16
Alnus cordata	Italian alder	BDM	
Alnus rhombifolia	white alder	BDL	
Annona cherimola	cherimoya	BES	
Araucaria bidwillii	bunya bunya	CEL	
Araucaria columnaris	coral reef araucaria	CEL	
Araucaria heterophylla	Norfolk Island pine	CEL	
Arbutus unedo	strawberry tree	BES	
Archontophoenix cunninghamian	king palm	PES	
Arecastrum romanzoffianum	queen palm	PES	
Bauhinia variegata	mountain ebony	BDS	
Betula pendula	European white birch	BDM	
Betula species	birch	BDM	94
Brachychiton populneus	kurrajong	BEM	
Brahea armata	Mexican blue palm	PES	
Brahea edulis	Guadalupe palm	PES	
Brahea species	brahea palm	PES	
Broadleaf Deciduous Large	broadleaf deciduous large	BDL	140
Broadleaf Deciduous Medium	broadleaf deciduous medium	BDM	
Broadleaf Deciduous Small	broadleaf deciduous small	BDS	
Broadleaf Evergreen Large	broadleaf evergreen large	BEL	
Broadleaf Evergreen Medium	broadleaf evergreen medium	BEM	
Broadleaf Evergreen Small	broadleaf evergreen small	BES	
Broussonetia papyrifera	paper mulberry	BDM	
Butia capitata	jelly palm	PES	
Calliandra tweedii	Trinidad flame bush	BES	
Callistemon citrinus	lemon bottlebrush	BES	
Callistemon viminalis	weeping bottlebrush	BES	
Calocedrus decurrens	incense cedar	CEL	

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

Data Collection – Calculating your Sample Size

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)	1189
5)	Standard deviation of stored CO_2 (kg)	978
6)	Expected proportion of tree survival (75% required)	75%
	Calculated sample size	115

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 the Tropical climate zone.

Age	BDL	BDM	BDS	BEL	BEM	BES	CEL	CEM	CES	Avg.	Std. Dev.
5	380	66	45	103	58	102	13	30	47		
10	1,282	249	152	354	185	281	203	127	167		
15	2,444	550	338	724	376	453	964	317	315		
20	3,638	957	610	1,175	615	588	2,021	621	475		
25	**4,719**	**1,450**	**976**	**1,673**	**883**	**695**	**2,021**	**1,059**	**640**	**1,189**	**978**
30	5,627	2,009	1,442	2,191	1,162	812	2,021	1,647	807		
35	6,364	2,610	2,013	2,711	1,434	992	2,021	2,402	974		
40	6,977	3,231	2,695	3,222	1,684	1,316	2,021	3,337	974		

Data Collection – Identifying your Random Sample of Planting Sites

Directions

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

No. Sites to Sample	Random List of Site IDs
1	69
2	97
3	134
4	200
5	170
6	116
7	133
8	236
9	195
10	104
11	21
12	139
13	215
14	186

1) In Column A create a numbered row for each of the sites to be sampled (110) in example.

2) In cell B6, replace the XXXX in the following formula with the total number of planted sites, =RANDBETWEEN(1,XXXX).

2) Replace the XXXX in the following formula with the total number of sites,
=LARGE(ROW($1:$XXXX)*NOT(COUNTIF($B$5:B5,ROW($1:$XXXX))),RANDBETWEEN(1,(XXXX+2-1)-ROW(B5)))

3) Copy and paste that formula into cell B7. 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 B7 down for as many rows as you are required to sample, the resulting values should all be unique.

5) Starting in cell B6 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.

Data Collection – Field Sample Data Collection Sheet

Directions

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

To request Credits, consult the Sample Size Calculator to determine the required number of random samples.

- Use the Random Sampling Tool to create a random list of site IDs to sample.
- 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: 08/11/2018 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

Sample Data

Directions

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	39	4	1	44	12	1	0	13	57	68	77	2.46	108
Brdlf Decid Med (30-50 ft)	94	26	1	1	28	12	3	0	15	43	60	65	2.19	61
Brdlf Decid Small (<30 ft)	16	6	1	0	7	3	0	0	3	10	60	70	1.60	11
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	71	6	2	79	27	4	0	31	110	65	72		180

Credits at Years 4 and 6 After Planting

Directions
Using the information you provide and background data, the tool calculates the amount of Credits that could be issued at years 1 (10%), 4 (40%) and 6 (30%) after planting. A mortality deduction (% loss) is applied to account for tree losses based on sampling results.

Table 6. Credits are based on 10%, 40% and 30% at Years 1, 4, and 6 after planting, respectively, of the projected CO2 stored by live trees 25-years after planting. These values account for tree losses based on sampling results and 5% buffer pool deduction.

						10%	40%	30%
	No. Sites Planted	**No. Live Trees**	**Mortality Deduction (%)**	**Tot. 25-yr CO_2 stored w/ mortality (t)**	**Tot. 25-yr CO_2 stored minus 5% deduction (t)**	**Initial CO_2 (t)**	**4 Years CO_2 (t)**	**6 Years CO_2 (t)**
BDL	140	108	0.23	510.0	484.5	48.45	193.80	145.35
BDM	94	61	0.35	88.8	84.3	8.43	33.73	25.30
BDS	16	11	0.30	10.9	10.4	1.04	4.15	3.11
BEL	0	0	0	0.0	0.0	0.00	0.00	0.00
BEM	0	0	0	0.0	0.0	0.00	0.00	0.00
BES	0	0	0	0.0	0.0	0.00	0.00	0.00
CEL	0	0	0	0.0	0.0	0.00	0.00	0.00
CEM	0	0	0	0.0	0.0	0.00	0.00	0.00
CES	0	0	0	0.0	0.0	0.00	0.00	0.00
	250	180	0.28	609.7	579.2	57.92	231.68	173.76

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 Stored (kg) End of Year 25 (w/ mortality)	CO2 (t) Stored at the End of Year 25 Minus 5% Buffer Deduction
Brdlf Decid Large (>50 ft)	140	2.46	44	108	207,641.2	484.50
Brdlf Decid Med (30-50 ft)	94	2.19	28	61	40,607.5	84.33
Brdlf Decid Small (<30 ft)	16	1.60	7	11	6,830.3	10.38
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		79	180	255,079.1	579.21

CO_2 Summary

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	579.21	$11,584.20	$23,168.39
Brdlf Evgrn	0.00	$0.00	$0.00
Conif Evgrn	0.00	$0.00	$0.00
Total	579.21	$11,584.20	$23,168.39
	CO_2 (t)	**Total $**	**Total $**
Grand Total CO_2 (t) at 25 years:	579.21	$11,584.20	$23,168.39
High Est. with Error:	666.09	$13,321.82	$26,643.65
Low Est. with Error:	492.33	$9,846.57	$9,846.57
± 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 7. Co-Benefits per year after 25 years (all live trees, includes tree losses)

Ecosystem Services (Resource Units)	Resource Units (Totals)	Resource Unit/site	Total $	$/site
Rain Interception (m3/yr)	1,038.93	4.16	$502.26	$2.009
CO2 Avoided (t, $20/t/yr)	10.46	0.04	$209.18	$0.837
Air Quality (t/yr)				
O3	0.0819	0.0003	$2,966.76	$11.867
NOx	0.0367	0.0001	$1,330.25	$5.321
PM10	0.0465	0.0002	$5,258.16	$21.033
Net VOCs	-0.1759	-0.0007	-$1,295.22	-$5.181
Air Quality Total	-0.0109	0.0000	$8,259.96	$33.04
Energy (kWh/yr & kBtu/yr)				
Cooling - Elec.	23,486.42	93.95	$3,823.82	$15.30
Heating - Nat. Gas	14,510.13	58.04	$188.82	$0.76
Energy Total ($/yr)			$4,012.64	$16.05
Grand Total ($/yr)			$12,984.04	$51.94

Single Tree Final Credit Quantification and Tool

Overview

Project Operators will use and update their Data Collection sheet created at planting. See page 10 above. The Tool described below will guide them through final quantification at Year 26.

The P.O. calculates the amount of CO_2 stored by live project trees 26 years after initial planting, based on sampling of the resource. The following steps are required and illustrated for a hypothetical planting of 250 street/front yard sites in Sacramento, with 95 trees sampled 26-years after planting.

This tool is used to support a request for final credits 26 years after planting when most trees have matured. The approach calculates the amount of CO_2 stored by live project trees in metric tonnes (t) on a tree-by-tree basis, based on sampling of a full inventory of the resource.

Steps

1) Create a planting list that contains data on the numbers of trees planted by species. Other information to record includes tree location and date planted.
2) Use the information gathered in step one to fill-in the Planting List (Table 1) by recording the number of sites planted for each tree species. We use the term "site" instead of "tree" because some planted trees may no longer be present in the sites where they were planted.
3) Use the Sample Size Calculator (Table 3) to determine the number of sites to sample. See directions on the sheet for more information.
4) Create a random sample of sites to visit and collect data at each site. See the Random Sample sheet for more information. Use a DIFFERENT random sample each time credits are sought.
5) Visit and collect data at each site. For further instructions see the data collection sheet.
6) Enter the number of live trees sampled in each 1" dbh class by tree-type in the tables 5-7 on the Sampled Data sheet. Then enter the number of dead and not replaced (vacant) and dead that were replaced in tables 10-12.
7) In the CO2 Summary sheet, Table 16, enter the low and high price of CO2 in $ per tonne (t).

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 decurrens	green acacia	BEM	
Acacia longifolia	Sydney golden wattle	BES	
Acacia melanoxylon	black acacia	BEL	
Acer palmatum	Japanese maple	BDS	
Acer rubrum	red maple	BDL	
Acer saccharinum	silver maple	BDL	
Acer species	maple	BDL	
Agonis flexuosa	peppermint tree; Australian willow myrtle	BES	
Albizia julibrissin	mimosa	BDS	16
Alnus cordata	Italian alder	BDM	
Alnus rhombifolia	white alder	BDL	
Annona cherimola	cherimoya	BES	
Araucaria bidwillii	bunya bunya	CEL	
Araucaria columnaris	coral reef araucaria	CEL	
Araucaria heterophylla	Norfolk Island pine	CEL	
Arbutus unedo	strawberry tree	BES	
Archontophoenix cunninghamian	king palm	PES	
Arecastrum romanzoffianum	queen palm	PES	
Bauhinia variegata	mountain ebony	BDS	
Betula pendula	European white birch	BDM	
Betula species	birch	BDM	94
Brachychiton populneus	kurrajong	BEM	
Brahea armata	Mexican blue palm	PES	
Brahea edulis	Guadalupe palm	PES	
Brahea species	brahea palm	PES	
Broadleaf Deciduous Large	broadleaf deciduous large	BDL	140
Broadleaf Deciduous Medium	broadleaf deciduous medium	BDM	
Broadleaf Deciduous Small	broadleaf deciduous small	BDS	
Broadleaf Evergreen Large	broadleaf evergreen large	BEL	
Broadleaf Evergreen Medium	broadleaf evergreen medium	BEM	
Broadleaf Evergreen Small	broadleaf evergreen small	BES	
Broussonetia papyrifera	paper mulberry	BDM	
Butia capitata	jelly palm	PES	
Calliandra tweedii	Trinidad flame bush	BES	
Callistemon citrinus	lemon bottlebrush	BES	
Callistemon viminalis	weeping bottlebrush	BES	
Calocedrus decurrens	incense cedar	CEL	

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

Data Collection - Sample Size

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) Enter:	Expected proportion of tree survival	70%
	Calculated sample size	95

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.
3) Standard deviation of the average CO_2 stored for all tree types 25 years after planting is automatically filled in from the Table 4.
5) 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 (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, input this number into Cell D9, which will multipy your value by 100 and display it as a percentage). Note: if you do not have an estimate for tree survival, 75 should be entered.

Data Collection – Calculating a Random Sample of Planting Sites

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

No. Sites to Sample	Random List of Sites
1	129
2	48
3	64
4	148
5	188
6	201
7	97
8	26
9	65
10	233
11	205
12	167
13	95

Random Sampling Steps

1) Replace the XXXX in the following formula with the total number of sites, =RANDBETWEEN(1,XXXX). Enter this formula in cell B5.
2) Replace the XXXX in the following formula with the total number of sites, =LARGE(ROW($1:$XXXX)*NOT(COUNTIF($B$5: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 the amount of rows that is equivilant to the amount of sites 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.

Data Collection – Field Sample Data Collection Sheet

Directions

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

Soon after planting the trees for the project record the following information:

- Date of data collection.
- Names of the crew that collected that data.
- Site Id#, a unique number assigned to each spot a tree is planted.
- If the tree is the original one planted (original) or a replacement (replace#1, replace#2).
- If the tree is dead or missing (vacant site).
- Species (botanical name)
- Tree Id#, the unique number that conincides with each tree that was planted. 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 grow. 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 that gets replaced, that new tree will then be tree# 5.
- Diameter at breast height (dbh), this is typically taken at 1.37 meter from the ground. If you are unable to take the dbh measurement at this height please see the field guide found at, Roman, L., et al. Urban Tree Monitoring: Field Guide (In prep) General Technical Report, for further information. If a tree you are measuring has multiple stems (trunks) you will need to calculate the square root of the sum of squares of the diameters to calculate one value for the dbh:
  1) Measure the DBH of each stem.
  2) Square the DBH of each stem.
  3) Sum the squares of all the stems.
  4) Take the square root of the sum and use it as the DBH.

  Example: Given a tree with 3 stems that measure 10, 18, and 14 the combined DBH value is:
  sqrt(10^2 + 18^2 + 14^2) = 24.9
- Height (ht). These data are not used in this tool but can be helpful for other reasons such as, verifying you are collecting data at the same tree in subsequent monitoring sessions.
- Condition (cond), good, fair, poor, dead. These data are not used in this tool but can be helpful for other reasons such as, verifying you are collecting data at the same tree in subsequent monitoring sessions.
- x and y coordinates of where each tree is located. These data are used to accurately locate the site for remeasurement.
- 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.
- Notes, information concerning tree status, health, etc.
- During subsequent monitoring sessions you will use the same data sheet format. During these 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 Sheet

Date: | Crew:

site id#	live (orig/replace #1/replace #2)	dead/vacant site	species	tree id #	dbh1 (cm)	dbh2 (cm)	dbh3 (cm)	dbh4 (cm)	dbh5 (cm)	ht (m)	cond	x coord	y coord	image#1	image#2	Notes
1	RP#1		Celtis reticulata	4	5					15	Good					Original tree (#1) removed & replaced (#4)
2		vacant	Pistacia chinensis	2												Dead tree (#2) removed , not replaced
3	Original		Platanus racemosa	3	10	18	14			30	Fair					Originally planted tree (#3) alive

Sample Data

Table 14. Sample summary

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
Brdlf Decid Large (>50 ft)	140	34	4	1	39	12	1	0	13	52	65	75	2.69
Brdlf Decid Med (30-50 ft)	94	23	1	1	25	12	3	0	15	40	58	63	2.35
Brdlf Decid Small (<30 ft)	16	4	1	0	5	3	0	0	3	8	50	63	2.00
Brdlf Evgrn Large (>50 ft)	0	0	0	0	0	0	0	0	0	0	0	0	0
Brdlf Evgrn Med (30-50 ft)	0	0	0	0	0	0	0	0	0	0	0	0	0
Brdlf Evgrn Small (<30 ft)	0	0	0	0	0	0	0	0	0	0	0	0	0
Conif Evgrn Large (>50 ft)	0	0	0	0	0	0	0	0	0	0	0	0	0
Conif Evgrn Med (30-50 ft)	0	0	0	0	0	0	0	0	0	0	0	0	0
Conif Evgrn Small (<30 ft)	0	0	0	0	0	0	0	0	0	0	0	0	0
	250	61	6	2	69	27	4	0	31	100	61	69	

Total CO_2 - Final Credits at 26 Years After Planting

In Table 15 the tool infers the amount of CO_2 stored from the sample to the population of live trees.

Table 15. Grand Total CO_2 Stored (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	54,858.89	147.70
Brdlf Decid Med (30-50 ft)	94	2.35	25	59	23,048.57	54.16
Brdlf Decid Small (<30 ft)	16	2.00	5	10	813.48	1.63
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	78,720.94	203.49

CO_2 Summary

You can enter a price per tonne to see dollar values of Credits.

Table 16. CO_2 value

	CO2 $ per tonne
Low	$20.00
High	$40.00

Table 17. Summary of CO_2 stored

Tree-Type	**Total CO_2 (t) at 25 years**	**Low $ value**	**High $ value**
Brdlf Decid	203.49	$4,069.76	$8,139.52
Brdlf Evgrn	0.00	$0.00	$0.00
Conif Evgrn	0.00	$0.00	$0.00
Total	203.49	$4,069.76	$8,139.52
	CO_2 (t)	**Total $**	**Total $**
Grand Total CO_2 (t) at 25 years:	203.49	$4,069.76	$8,139.52
High Est. with Error:	234.01	$4,680.23	$9,360.45
Low Est. with Error:	172.96	$3,459.30	$3,459.30
± 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 in Resource Units per year and $ per year. Values include tree losses based on sampling results.

Table 18. Co-Benefits (per year, tree losses included)

Ecosystem Services	Resource Units (Totals)	Resource Unit/site	Total $	$/site
Rain Interception (m3/yr)	379.18	1.52	$781.31	$3.13
CO2 Avoided (t, $20/t/yr)	9.30	0.04	$186.05	$0.74
Air Quality (t/yr)				
O3	0.0514	0.0002	$567.06	$2.27
NOx	0.0126	0.0001	$354.77	$1.42
PM10	0.0268	0.0001	$556.29	$2.23
Net VOCs	0.0005	0.0000	$5.65	$0.02
Air Quality Total	0.0914	0.0004	$1,483.78	$5.94
Energy (kWh/yr & kBtu/yr)				
Cooling - Elec.	21,825.56	87.30	$2,544.86	$10.18
Heating - Nat. Gas	7,565.78	30.26	$94.15	$0.38
Energy Total ($/yr)			$2,639.01	$10.56
Grand Total ($/yr)			$5,090.14	$20.36

Canopy Initial Credit Quantification Method and Tool

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

Canopy Management Credit Quantification Method and Tool

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

Canopy Final Quantification Method

The PO calculates 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.

Attachment A

Approach for Establishing Carbon Dioxide Stored by Tree Canopy in Riparian Tree Planting Projects in Austin, TX

This Attachment A provides an example of the Riparian Tree Planting Quantification Method.

There are two different methods for quantifying carbon dioxide (CO_2) storage in urban forest carbon projects – the Single Tree Method (where planted trees are few or are scattered among many existing trees) and the Tree Canopy For Park-like Projects Method (where planted trees are relatively contiguous). Instead of using the traditional Tree Canopy Approach for riparian tree planting projects in Austin, we use a forest ecosystem approach. The traditional approach, which is based on the biometrics of open-growing urban trees, cannot adequately describe biomass distribution among closely-spaced trees and the dynamic changes in CO_2 stored in dead wood and understory vegetation as a riparian forest stand matures.

In our modified approach the amount of CO_2 stored after 25-years by planted project trees is based on the anticipated amount of tree canopy area (TC). The forecasted amount of CO_2 stored at 25-years is the product of the amount of tree canopy (TC) and the CO_2 Index (CI, t CO_2 per acre). This amount is the value from which the Registry issues credits in the amounts of 10%, 40% and 30% at Years 1, 4 and 6 after planting, respectively. A 5% buffer pool deduction is applied, with these funds going into a program-wide pool to insure against catastrophic loss of trees. At the end of the project, in year 25, the Operator will receive credits for all CO_2 stored, minus credits already issued.

To provide an accurate and complete accounting of carbon pools in these riparian projects we used the US Forest Service General Technical Report (GTR) NE-343, with its allometrics for the elm/ash/cottonwood forest ecosystem in the South Central region (Smith et al., 2006). The table we used (B50) provides carbon stored per hectare for each of six pools as a function of stand age. We used values for 25-year old stands for afforestation projects, because the sites contain little carbon in down dead wood and forest floor material at the time of planting. Data used to derive the 51 forest ecosystem tables came from U.S. Forest Inventory and Assessment plots. More information on methods used to prepare the tables can be found in Smith et al. (2006).

Following guidance in GTR NE-343 we adjusted the GTR NE-343 values for live wood, dead standing and dead down wood using local plot data provided by the team. According to the plot data the mean amount of C stored in all tree biomass was 24 t/ha. This value does not include biomass of invasive woody species. Lacking a measured breakdown of this total for trees among the live, standing dead, and down dead biomass components, the 24 t/ha was proportionately distributed as per the GTR (i.e., live: 87%, 20.9 t/ha; standing dead: 7%, 1.7 t/ha; down dead: 6%, 1.4 t/ha). The remaining three carbon pools (understory, forest floor and soil) remained the same as in GTR Table B50 because their values are independent of tree biomass. The customized values are shown below in Table 1. Carbon in the tree pool totals 24 t/ha and accounts for 33% of the total 71.9 t/ha after 25 years for this forest ecosystem. Soil organic carbon is the single largest pool (56%).

After conversions, **the CO_2 Index (CI) is 106.7 t CO_2 per acre of tree canopy (TC) and the forecasted amount of CO_2 stored after 25-years is the CI x TC.** This is the value from which the Registry will issue credits (Table 1).

Table 1. Estimated amounts of carbon stored in each pool at 25-years after planting for riparian forest projects in Austin, TX. These values are based on local plot data for these types of forests and values from GTR NE-343 for the elm/ash/cottonwood forest ecosystem in the South Central region.

elm/ash/cottonwood	t/C/ha	t/CO2/ha	t/CO2/ac	% total
live tree	20.9	76.8	31.08	29%
std dead tree	1.7	6.1	2.48	2%
understory	3.3	12.1	4.90	5%
down dead wood	1.4	5.1	2.07	2%
forest floor	4.4	16.1	6.53	6%
soil	40.2	147.4	59.68	56%
total	71.9	263.6	106.73	100%

Quantification at end of Year 25

- Project provides images of the Project Area from any telemetry, imaging, remote sensing, i-Tree Canopy, or UAV service, such as Google Earth and estimate the area in tree canopy cover (acres).
    - Projects can use i-Tree Canopy and point sampling to calculate canopy cover. Using i-Tree Canopy, continue adding points until the standard error of the estimate for both the

tree and non-tree cover is less than 5%. I-Tree Canopy will supply you with the standard errors.

- If tree canopy cover is determined using another approach, such as image classification, a short description of the approach should be provided, as well as the QA/QC measures that were used. A tree cover classification accuracy assessment should be conducted, as with randomly placed points, and the percentage tree cover classification accuracy reported.

- Project calculates total CO_2 storage at end of Year 25 as follows:
  - Multiply the CI (106.73 t CO_2/ac TC) times the acres of TC (tree canopy) in the Project Area.

References

Smith, James E.; Heath, Linda S.; Skog, Kenneth E.; Birdsey, Richard A. 2006. Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. Gen. Tech. Rep. NE-343. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 216 p.

Appendix C

Verification for Tree Planting Projects

Version 7

December 2018

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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 accredit third-party verifiers who 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 or the Project Operator will retain a third-party verifier to verify compliance with this Protocol.
- 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 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 Credits

Table C.1 displays the various verification requirements to be performed upon request by a Project Operator for credits under Section 9 of the Planting Protocol. Further guidance on elements in Table C.1 follows 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 or Transfer from Owner to PO

5.	Commencement	5	Proj. Documentation
6.	Proj Documentation	4	Check
7.	Proj Duration	3	Signed PIA
8.	Additionality		Registry Program
	Performance Standard Baseline	App. D	
	Legal requirements Test	4.1	Check PIA and Ords;
	Performance Guarantee Credits	3	Registry
9.	For Single Tree Credit Quant, after planting, Yr 4, and Yr 6; PO's Credit Mortality and Verif. Assessment:	9, App. B	
	1. After Planting:		
	Imaging, or PO Decl. of Planting and Decl. Of Peer Verifier		See Guidance in Section 5.6
	2. After Years 3 and 5:		
	3. Accuracy of Process and Documents:		Check approp. Quant Tool
	a. Sample Size Calculation		Same
	b. Randomization of Sample		
	c. Calculations		Same
	d. Integrity of Spreadsheet		Same
	4. Field Data and Inputs into Spreadsheets:		
	a. Data from sampled trees		Geo-coded Photos of Sample Trees
	b. Data Input accuracy		Check inputs

10.	For Canopy Credit Quant:		
	1. After Planting:		
	a. Imaging, or PO Decl. of Planting and Decl. Of Peer Verifier		See Guidance in Section 5.6
	2. After Year 3:		
	a. Imaging or geo-coded photos with PO Decl.		
	3. After Year 5:		
	a. Imaging or geo-coded photos with PO Decl.		
	PO's Report	App. A	Check
	Reversals	10	PIA, PO's Report, sample data

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
	Performance Standard Baseline	App. D	
	Legal requirements Test	4.1	Check PIA and Ords;
	Performance Guarantee Credits	3	Registry
9.	PO's Single Tree Quant Tool Spreadsheet:	9 and App. B	
	5. 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
6.	7. 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, 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 follows 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	7	Proj. Documentation
6.	Proj Documentation	App. A	Check

7.	Proj Duration	5	Signed PIA: for all above: Signed Decl. of Compliance
8.	Additionality		Registry Program
	Performance Standard Baseline	App. D	
	Legal Requirements Test	4.1	Check PIA and Ords
	Performance Guarantee Credits	3	Registry
9.	PO's Canopy Quant Tool Spreadsheet:	9 and App. B, C	
	8. Accuracy of Process and Documents:		Check approp. Quant Tool
	a. Calculations		Same
	b. Integrity of Spreadsheet		Same
			Same
	9. 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	10	PIA, Decl. of Compliance, PO's Report, sample data

	Credit Hold-backs until Year 26 and Buffer Pool Contributions	9	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 Declaration of Ownership and Right to Receive Credits, or, if the Project Operator does not own the land upon which project trees are planted, a written agreement transferring credits from the owner to the Project Operator. 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 7 of the Protocol.

5.4 Additionality

Verification requires confirmation of performance guarantee credits. The PIA must provide for that mechanism, and the Registry must have a stock of guarantee credits in its ACR or Verra account.

Verification also requires review of the Performance Standard Method applied at the Registry level, and review of the PIA for inclusion of attestation to compliance with the Protocol, which includes the Legal Requirements Test. Further review of local ordinances of laws may be required to give a reasonable assurance that this requirement has been met.

5.5 Spreadsheet Review

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 CO2.

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

5.6 Verification of Canopy Planting and Credit Progress

The following verification data is required within one year of planting.

Declaration of Planting: a statement by the Project Operator that includes the following, with any supporting documentation:

- Dates of planting
- Attendance and list of planters
- Number of trees planted by species
- Invoices for trees planted, or invoices or a statement from the party who funded the tree purchase or supplied the trees attesting to the number of trees purchased, or any other reliable estimate of trees planted

- Any reporting to the owner or public body re the planting, invoices, costs, or other data re the planting
- Geo-coded photos of the tree stock and planting event(s)

Declaration of Peer Verifier on Canopy Planting. Confirms that

- They have attended at least one planting event for the project and has verified from the planting schedule that any other scheduled planting events occurred
- They have reviewed the data from the Declaration of Planting and confirm that it accurately reflects their own observations of planting activities

Verification data required after Years 3 and 5

- Project provides images of the Project Area from any telemetry, imaging, remote sensing, or UAV service, such as Google Earth.
- Project uses i-Tree Canopy and point sampling to calculate canopy cover:
    - Using i-Tree Canopy, continue adding points until the standard error of the estimate for both the tree and non-tree cover is less than 5%. I-Tree Canopy will supply you with the standard errors.

Progress Requirements for canopy projects after Years 3 and 5:

- After Year 3, projects must show canopy coverage of at least 12% of the Project Area (3 years as a percent of 25-year project duration)
- After Year 5, projects must show canopy coverage of at least 20% of the Project Area (5 years as a percent of 25-year project duration)

Note: if projects exceed these Progress Requirements, they will not receive credits early or out of schedule. If projects fail to meet the Progress Requirements, they will not be eligible to request credits until they meet the Progress Requirements.

The above requirements reflect the following unique factors about canopy plantings that seek to create canopy quickly:

- Canopy plantings do not track tree loss because they are ecological projects seeking canopy. Canopy plantings anticipate relatively high tree loss compared to single tree or street-tree type plantings.
- Canopy is generated by the recruitment of species on the site and by planting a variety of smaller and larger species that provide canopy quickly. Larger species that out-compete others provide longer-term canopy coverage.
- Because of the above, the precise number of trees planted is not the key to a successful canopy project. That success often relies on recruitment and the competition of species that enable the success of some trees at the expense of others.

6. Completing Verification

A verification report and statement must be completed in order for credits to be issued. That report and statement 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.

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

Appendix D

Permanence, Timing of Crediting, and Performance Standard Methodology

Version 7

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The Planting Protocol required careful analysis and application of three particular protocol principles – project duration (or permanence), timing of the issuance of credits (ex post versus ex ante credits), and additionality as it relates to a project-specific baseline or a performance standard baseline methodology. This Appendix D summarizes key elements of the Drafting Group's analysis and discussion of these three protocol elements.

The Drafting Group developed the Performance Guarantee of a retired ACR or Verra credit for each City Forest Carbon+ Credit as a way to address these three protocol elements beyond the specific requirements imposed by the Planting Protocol on city forest planting projects. The retired ACR or Verra credit provides the atmospheric reduction of an offset credit that meets standards of permanence, ex post crediting, and additionality.

The Performance Guarantee allowed the Drafting Group to develop requirements for city forest planting projects that address these three elements without rendering the protocol unusable in the real world. As noted in the introduction to the Protocol, the Drafting Group was highly aware that the two prior urban forest protocols have had no applicants. The Drafting Group had little interest in a protocol that could not be implemented. The Drafting Group describes below its analysis of these issues and the rationale behind developing a performance guarantee for each City Forest Carbon+ Credit.

1. Permanence

The Protocol Drafting Group was unanimous in believing that the longest possible project duration commitment that could be made by planting project operators would be 25 years. Elected and agency officials in cities as well as local non-profit tree organizations simply do not have the money and will not take the risk of a longer commitment for expensive planting projects.[1] Given that almost all planting projects will be done on public property like park land, it is highly likely that these public project trees will remain long past 25 years. But city officials and non-profit tree organizations will not be willing to enter into planting projects with a duration commitment longer than 25 years.

A 25-year project duration period could be defended for the following reasons:

- The urgency contained within the scientific conclusions of the IPCC, 2018: Global warming of 1.5°C is likely to occur by 2030 without immediate action that goes beyond any current efforts
- The scientific and policy considerations that recognize the many environmental, social, and economic benefits of city forests
- The fact that city forests are essentially public resources
- The fact that most city forest projects will be on public property and thus will likely last beyond 25 years
- Project operators have every incentive to maintain city forest projects after 25 years. City trees are not grown for harvest, so there is no monetization for city trees other than through carbon or ecosystem credits. Project Operators are thus highly motivated to obtain credits for additional growth beyond 25 years.

[1] Note that cities and counties will commit to 40 and even 100 year easements and recorded encumbrances for preservation projects, in contrast to planting projects. When a city or county preserves forested urban land, it usually does so with a recorded encumbrance and has made the commitment financially to preserve that land for public accessibility, as a park for example.

> In addition, most project costs are expended in planting and early survival, so those costs are sunk by year 25. Carbon revenues after year 25 are not eroded by the high costs of planting and early maintenance.

But rather than stake the credibility of the Planting Protocol on an extended defense of a 25-year project duration, the Drafting Group developed the Performance Guarantee program. Every CFC Credit thus contains an ACR or Verra credit that has already removed one ton of CO2e from the atmosphere and meets a full permanence standard, as well as all other ICROA standards for crediting set out in ICROA Offset Standard Review Criteria, Essential Criteria, Section 5 (2017). The buyer obtains a City Forest Carbon+ Credit, including both the ACR/Verra credit and the quantified CO2 reduction and quantified co-benefits issued under and subject to all of the criteria, standards, and requirements of the City Forest Planting Protocol.

2. Timing of Credit Issuance (ex post and ex ante crediting)

The Drafting Group was also aware that almost all planting projects in cities require up-front or early funding. Projects cannot wait for 25 years to receive funding, and there are no realistic financing mechanisms to fund planting and early maintenance. Yet, as noted in the protocol and in the White Paper, there are extremely strong practical and policy reasons in favor of encouraging city forest projects. And because public funding is pervasively inadequate, any revenue from carbon credits is a significant benefit.

To strengthen the rigor and stringency of credit issuance, the Drafting Group developed a process for credit issuance that provides for credits to be issued upon certain survival milestones and after sampling, quantification, and verification. See Section 9 of the Protocol.

Specifically, the credits are based on survival and on estimated carbon storage over a 25-year project duration, minus deductions for a buffer pool, deductions for project mortality of 20% at initial crediting, deductions for actual mortality at two intervals, and for a retainage of 20% of credits until the end of the 25-year project duration.

Despite these multiple safeguards, the Drafting Group recognized that some of these credits will be issued before the end of the project and thus could be viewed as ex ante credits. And the Drafting group understands the strong prohibition on ex ante credits, no matter the value of city forests or their decline. Accordingly, the Drafting Group developed its program for Ex Post Performance Guarantee for the City Forest Carbon+ Credits. The retired ACR or Verra credit provides the ex post atmospheric reduction of CO_2e. The CO_2 stored and the quantified rainfall interception, air quality, and energy savings of the City Forest Carbon+ Credit are all in addition to the atmospheric benefit of the retired ACR or Verra credit.

Some commentators have asked how the City Forest Carbon+ Credit can afford to include a retired ACR or Verra credit. The answer to that question is that Project Operators are not offering City Forest Carbon+ Credits to compete on price with other credits. The City Forest Carbon+ Credits are extremely valuable to buyers as well as to cities. The quantified co-benefits alone are worth far more in dollar value of avoided costs than the carbon at current carbon prices in the voluntary market. In addition, Carbon+ Credits offer many other environmental, social, and economic benefits, with all of the benefits being delivered in cities and towns, where people live and work. The media value to buyers is very high, because urban populations have high numbers of customers, employees, and voters. And many entities, from the City of Austin to private-sector companies, seek a locally sourced credit. So

Project Operators are offering the City Forest Credits as premium credits, with room in the pricing to include a retired ACR or Verra credit.

3. Additionality and the Performance Standard Baseline per WRI GHG Protocol

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

However, the WRI GHG Protocol clearly states that either a project-specific test or a performance standard baseline is acceptable.[2] 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.

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

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

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

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

Table 2.1 Performance Standard Factors

WRI Perf. Standard Factor	**As Applied to Urban Forestry**
Describe the project activity	Increase in urban trees
Identify the types of candidates	Cities and towns, quasi-governmental entities like utilities, watersheds, and educational institutions, and private property owners
Set the geographic scope (a national scope is explicitly approved as the starting point)	Could use national data for urban forestry, or regional data

Set the temporal scope (start with 5-7 years and justify longer or shorter)	Use 4-7 years for urban forestry
Identify a list of multiple baseline candidates	Many urban areas, which could be blended mathematically to produce a performance standard baseline

The Performance Standard methodology approves of the use of data from many different baseline candidates. In the case of urban forestry, those baseline candidates are other urban areas.[3]

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

Data on Tree Canopy Change over Time in Urban Areas

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, see footnote 7)

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

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					

City	Abs Change UTC (%)	Relative Change UTC (%)	Ann. Rate (ha UTC/yr)	Ann. Rate (m2 UTC/cap/yr)	Data Years
Chicago, IL	-0.5	-2.7	-70	-0.2	(2005–2009)
Detroit, MI	-0.7	-3.0	-60	-0.7	(2005–2009)
Kansas City, MO	-1.2	-4.2	-160	-3.5	(2003–2009)
Minneapolis, MN	-1.1	-3.1	-30	-0.8	(2003–2008)
Mean changes	-0.9	-3.3	-80.0	-1.3	
Std Error	0.2	0.3	28.0	0.7	
WEST					
Albuquerque, NM	-2.7	-6.6	-420	-8.3	(2006–2009)
Denver, CO	-0.3	-3.1	-30	-0.5	(2005–2009)
Los Angeles, CA	-0.9	-4.2	-270	-0.7	(2005–2009)
Portland, OR	-0.6	-1.9	-50	-0.9	(2005–2009)
Spokane, WA	-0.6	-2.5	-20	-1.0	(2002–2007)
Tacoma, WA	-1.4	-5.8	-50	-2.6	(2001–2005)
Mean changes	-1.1	-4.0	-140.0	-2.3	
Std Error	0.4	0.8	67.8	1.2	

These data have been updated by Nowak and Greenfield.[4] The 2012 data show that urban tree canopy is experiencing negative growth in all four regions. The 2018 data document continued loss of urban tree cover. Table 3 of the 2018 article shows data for all states, with a national loss of urban and community tree cover of 175,000 acres per year during the study years of 2009-2014.

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

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

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

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

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

- Because almost no urban trees are planted now with carbon as a decisive factor, urban tree planting done to sequester carbon is additional;
- Because almost no urban trees are currently planted with more than a 3-year commitment, the 25-year commitment required by this Protocol will result in substantial additional trees surviving to maturity;
- Because the urban forest is a public resource, and because public funding falls far short of maintaining tree cover and stocking, carbon revenues will result in additional trees planted or in maintenance that will result in additional trees surviving to maturity;
- Because virtually all new large-scale urban tree planting is conducted by governmental entities or non-profits, or by private property developers complying with governmental regulations (which would not be eligible for carbon credits under our protocol), and because any carbon revenues will defray only a portion of the costs of tree planting, there is little danger of unjust enrichment to developers of city forest carbon projects.

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.*[5]

The policy considerations weigh heavily in favor of "highly desirable" planting and preservation projects to reverse tree loss for the public resource of city forests. Additionality is satisfied through the three elements contained herein:

- the legal requirements test in Section 4.1,
- the performance standard method articulated in the WRI GHG Protocol as applied above, and
- the Performance Guarantee of an ACR or Verra credit retired for each City Forest Carbon+ Credit issued.

Additionality is strengthened by the following:

- Because almost no urban trees are currently planted with more than a 3-year commitment, the 25-year commitment required by this Protocol will result in substantial additional trees surviving to maturity;
- Because the urban forest is a public resource, and because public funding falls far short of maintaining tree cover and stocking, carbon revenues will result in additional trees planted or maintenance that will result in additional trees surviving to maturity.

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