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Urban Forestry
Carbon Offset Protocol 2.0

July 11, 2017

Duke Carbon Offsets Initiative
DUKE UNIVERSITY

Table of Contents

Abbreviations and Acronyms

C	Carbon
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DBH	Diameter at breast height (4.5 feet from ground)
DCOI	Duke Carbon Offsets Initiative
GHG	Greenhouse gas
ISA	International Society of Arboriculture
KML	Keyhole Markup Language
$MtCO_2e$	Metric ton of carbon dioxide equivalent
N_2O	Nitrous oxide
USFS	United States Forest Service
UTP	Urban Tree Planting
UTP Owner	Urban Tree Planting Owner
UTP Op	Urban Tree Planting Operator
UTPM	Urban Tree Planting Maintainer

Duke Carbon Offsets Initiative Background

In 2007, Duke University signed the American College and University Presidents' Climate Commitment (ACUPCC) and set a target of achieving climate neutrality by 2024. To be climate neutral, Duke will have to offset an estimated 185,000 metric tons per year of carbon dioxide beginning in 2024. The Duke Carbon Offsets Initiative (DCOI) was created as a branch of Sustainable Duke to help Duke University reach climate neutrality. Since the DCOI's inception in 2009, it has developed a number of innovative carbon offset programs in swine waste-to-energy, energy efficiency, residential solar, and now, urban forestry.

Vision

To make Duke University a model climate-neutral institution and to lead peer institutions in their efforts to become climate neutral.

Mission

- To meet Duke University's climate neutrality goal by 2024 by **developing and implementing the University's strategy** for identifying, creating, and purchasing carbon offsets;
- To implement the strategy in a way that **provides educational opportunities** for students, faculty, and staff;
- To **prioritize local, state, and regional offsets that provide significant environmental, economic, and societal co-benefits** beyond the benefits of greenhouse gas reduction; and
- To **facilitate and catalyze high-integrity, unique offset projects** by serving as a resource for other institutions.

Scope

This protocol provides the procedure for determining carbon dioxide equivalent (CO_2e) storage associated with urban tree plantings as part of the DCOI-Durham Urban Tree Planting Program ("Program").

Protocol Developer

This protocol was developed by the Duke Carbon Offsets Initiative at Duke University.

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Protocol Description

This urban forestry carbon offset protocol ("Protocol") outlines the methodology for measuring the carbon offsets and documenting project co-benefits – the non-GHG related project benefits – generated from an urban tree planting project. This protocol should be used to ensure that the carbon offsets generated from the project meet the basic criteria of a carbon offset:

- **P**ermanent – The reduction must last in perpetuity;
- **A**dditional – The reduction would not have occurred during a business-as-usual scenario;
- **V**erifiable – The reduction must have been monitored and confirmed to have occurred;
- **E**nforceable – The reduction must be counted only once and then retired; and
- **R**eal – The reduction must actually have occurred and not be the result of flawed accounting.

In addition to P.A.V.E.R., this protocol provides information on co-benefits that Duke University considers when developing projects, such as educational, social, environmental, economic, scalability, and public relations and partnership benefits. Co-benefits of carbon offset projects are often key reasons cited in decisions to implement offset projects and are principal factors determining offsets' value. Co-benefits typically build climate resilience within their localities and prepare communities for climate change impacts.

This protocol informs project implementers on how to develop a project that meets the PAVER requirements to generate carbon offsets and tangibly impact the climate, but it also strives to incentivize projects with high co-benefits. Through this protocol, we propose the fusing of climate mitigation and climate adaption through the innovative practice of "Offset Bundling" (see section titled 'Alternate Option for Meeting PAVER Requirements').

This protocol adapts various requirements and definitions from the Climate Action Reserve's (CAR) Urban Tree Planting Project Protocol.[1] However, depending on program needs, these conditions could be adjusted.

Benefits of Trees and Carbon Offsets

Trees sequester carbon by fixation through photosynthesis. Assuming urban trees are healthy and properly managed, this carbon is accumulated and stored throughout the life of the tree thus serving as a carbon sink. While urban forests are less dense than traditional forests, their widespread presence alone makes them an important carbon sink. A 2013 study found urban/community trees in the United States annually sequester 184.6 million metric tons of CO_2 equivalent and store 4.99 billion metric tons of CO_2 equivalent, a figure larger than the 2012 CO_2 emissions from the entire European Union[2] (Nowak, 2013). Carbon sequestration within a city can be maximized by planting new trees and maintaining the health of those trees.

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[1] http://www.climateactionreserve.org/wp-content/uploads/2014/07/Urban_Tree_Planting_Project_Protocol_V2.0.pdf

[2] Annual European Union Greenhouse Gas Inventory 1990–2012 and Inventory Report 2014: http://www.eea.europa.eu/publications/european-union-green house-gas-inventory-2014

In addition to storage of carbon, trees provide many other health, environmental, and economic benefits. Trees reduce air and water pollution, absorb excess storm water, provide habitat and food for animals and pollinators, offer education and volunteer opportunities to students and community members, increase the health of citizens, and can lower utility bills by providing shade for homes.

Finally, of note, urban forestry offset programs can benefit local communities where emissions are occurring. By planting trees within a city, the city and its citizens can be positively impacted by the aforementioned benefits. Urban tree planting projects can both reduce CO_2 globally and benefit local communities.

Definitions

This protocol uses the following definitions provided by the Climate Action Reserve (CAR) Urban Tree Planting Project Protocol (2.0) and the US Environment Protection Agency:

- ***Carbon Dioxide Equivalent (CO_2e) Emissions*** is a metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential (GWP). Carbon dioxide equivalents are commonly expressed as metric tons of carbon dioxide equivalents ($MTCO_2e$). The carbon dioxide equivalent for a gas is derived by multiplying the tons of the gas by the associated GWP. (US EPA)
- ***Carbon Offset or Carbon Credit*** is equal to one metric ton of carbon dioxide equivalent ($MtCO_2e$) and can be used to reduce the emissions of an entity by one $MtCO_2e$ or sold to another entity for an agreed upon price.
- ***Carbon Offset Reversal*** is "a decrease in the stored carbon stocks associated with the GHG reductions and removals that occurs before the end of the project life." This can happen when the trees within the project are negatively affected by human activity (avoidable) or by a disease, drought, etc (unavoidable). The impact from these types of events should be quantified and subsequently the calculated amount of carbon offsets should be retired from the available buffer pool. (CAR)
- ***Greenhouse Gas (GHG)*** means any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include[3]:
  - carbon dioxide (CO_2)
  - methane (CH_4)
  - nitrous oxide (N_2O)
  - Fluorintated gases (chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride) (US EPA)
- ***Unavoidable Reversal*** "is any Reversal not due to the Project Operator's negligence, gross negligence or willful intent, including, but not limited to, wildfires or disease that are not the result of the Project Operator's negligence, gross negligence or willful intent." (CAR)
- ***Urban Tree Planting (UTP) Project Definition*** is a planned set of activities designed to increase the removals of CO_2 from the atmosphere, or reduce or prevent emissions of CO_2 to the atmosphere, through increasing and/or conserving urban forest carbon stocks. Benefits from urban tree planting activities occur when the net CO_2e (CO_2e

[3] http://www.epa.gov/climatechange/ghgemissions/gases.html

stored minus CO_2e emitted) associated with planted trees exceeds baseline tree planting CO_2. (CAR)

- ***Verification*** is "the process of reviewing and assessing all of a project's reported data and information to confirm that the project operator has adhered to the requirements of this protocol." (CAR)

Project Participants

- ***Urban Tree Planting (UTP) Owner*** is a corporation, a legally constituted entity (such as a utility or special district), city, county, state agency, educational campus, individual(s), or a combination thereof that has legal control of any amount of urban forest carbon within the Project Area. Control of urban forest carbon means the UTP Owner has the legal authority to effect changes to urban forest carbon quantities (right to plant or remove, for example). Control of urban forest carbon occurs, for purposes of satisfying this protocol, through fee ownership perpetual contractual agreements, and/or deeded encumbrances. This protocol recognizes the fee owner as the default owner of urban forest carbon where no explicit legal encumbrance exists. Individuals or entities holding mineral, gas, oil, or similar de minimis interests without fee ownership are precluded from the definition of UTP Owner.

- ***Urban Tree Planting Operators*** must contract with the UTP Owner to obtain ownership of the urban forest carbon created from the project. The UTP Operator is thereby responsible for project quantification, monitoring, reporting, and contracting with a third-party to verify the carbon. The Project Operator is responsible for any reversals associated with the project. In all cases where multiple Urban TP Owners participate in a UTP Project, the Project Operator must secure an agreement from all other UTP Owners that assigns ownership of the urban forest carbon to the Project Operator.

- ***Urban Tree Planting Maintainer*** is an entity responsible for maintaining the health of all project trees across the project timeline. Project Maintainers can be the UTP Owner, municipal tree crews, contractors, or volunteers trained in best industry practices such as the International Society of Arboriculture. The UTP Maintainer is also responsible for documenting all found tree deaths and submitting them to the UTP Operator for review.

Eligibility Conditions

This protocol uses the following eligibility conditions provided by the CAR Urban Tree Planting Project Protocol. However, depending on program needs, these conditions could be adjusted as long as they are approved by the DCOI.

Any Planting included in a Project shall meet the following conditions:

- ***Project Location:*** Projects must be located within at least one of the following:

A. The Urban Area boundary ("Urban Area"), defined by the most recent publication of the United States Census Bureau; [4]
B. The boundary of any incorporated city or town created under the law of its state;
C. The boundary of any unincorporated city, town, or unincorporated urban area created or designated under the law of its state;
D. A zone or area designated by any governmental entity as a watershed or for source water protection, provided the designated zone or area overlaps some portion of A, B, or C above;
E. A transportation, power transmission, or utility right of way, provided the right of way begins, ends, or passes through some portion of A, B, C, or D above.

Project Area: The Project Area is the geographic extent of the UTP Project. The Project Area may be made of consolidated or disaggregated polygons. An electronic file must be made available which identifies the project boundaries of the project. There are no size limits for UTP Projects. End-of-life use of fallen, damaged or management directed tree removals is accepted and encouraged through this protocol. End-of-life use of trees must adhere to management principles and removals must remain within anticipated mortality rates, but these trees should be used to reduce the purchase of new wood products where possible. Areas previously used for commercial lumber products are considered on a case-by-case basis by the Duke Carbon Offsets Initiative.

- ***Project Commencement:*** A Project commences when the Project Operator submits the project for Registry or GHG Program inclusion, provided the Registry or GHG Program approves that application within six months of submittal.

- ***Additionality:*** The Project must yield surplus GHG emission reductions and removals that are additional to what would have occurred in the absence of funding for the carbon offset project. The additionality checklist and protocol requirements for determining eligibility are listed in the section "Procedure for Determining Additionality."

- ***Legal Requirement:*** UTP Projects must achieve GHG reductions or removals above and beyond any GHG reductions or removals that would result from compliance with any federal, state, or local law, statute, rule, regulation, or ordinance. Projects must also achieve GHG reductions and removals above and beyond any GHG reductions or removals that would result from compliance with any court order or other legally binding mandates.

- ***Performance Standard Test:*** Projects must achieve reductions or removals above and beyond any GHG reductions or removals that would result from engaging in business-as-usual activities. This protocol uses the current business-as-usual within the United States in which more trees are removed than planted each year as a national baseline and recognizes that the use of this baseline would legitimize all newly planted trees as additional, thereby allowing business-as-usual tree planting efforts to pass additionality. Therefore, this protocol goes beyond this national baseline by requiring completion of

[4] http://www.census.gov/geo/maps-data/maps/2010ua.html

the additionality checklist as found the "Procedure for Determining Additionality" to maintain a rigorous project-by-project test for additionality.

- ***Project Crediting Period:*** The crediting period for a UTP is 20 years. Projects may be renewed but must calculate an updated baseline. The original baseline may be held throughout the 20-year crediting period. An updated baseline must ensure that a minimum planting is maintained and no new laws or regulations have been passed changing planting standards.

- ***Minimum Time Commitment:*** Projects must monitor, and report project data through to the end of a verification period, at which time the UTP Operator may choose to continue or discontinue the project. The project must maintain quantified standing carbon within the project area and remain in accordance with a signed project contract that provides for appropriate recourse in the event of a project reversal and the release of the project's stored standing carbon.

Procedure for Demonstrating High Quality Offsets

This section will discuss the components of a high-quality carbon offset with in-depth descriptions of P.A.V.E.R. requirements and co-benefits.

Offset Criteria and Definition	Required Data and Program Procedures
Permanent The reduction must last in perpetuity and the emission reductions cannot be reversed.	It is important to ensure the longevity and health of trees within the program for them to efficiently store as much carbon as possible. Trees in urban settings are subject to a variety of stressors including minimal rooting zone issues, poor soil quality, drastic temperature fluctuations, lack of water, toxicity, and human interactions. These issues increase the mortality rate of urban trees when compared to non-urban trees and are most pronounced during the first 10 years of growth when trees are adapting to their harsher environments, establishing root systems, and building resilience against these factors. An appropriate management plan for the climate region and species involved should include at a minimum: root zone protection, watering, pruning, monitoring for disease or infestation, and replacement of dead trees. Despite a robust management plan, higher mortality rates are still anticipated when compared to non-urban trees. Therefore, it is important to determine a buffer pool to take this into account, or use a carbon offset bundle to mitigate risk. For more information on these options, please read the "Buffer Pool" and "Offset Bundle" sections below.
Additional The reduction would not have occurred	To demonstrate additionality, the project must show that there are significant barriers to planting more trees, such as funding or staff limitations. Projects must also show how they remove barriers and result in an increase in tree planting and therefore an increase in carbon

during a business-as-usual scenario	storage. For more information about additionality, please read the "Procedure for Determining Additionality" section of this document.
Verifiable The reduction must have been monitored and confirmed to have occurred	At a minimum, the required data for this is the height and diameter at breast height (DBH) of the trees to calculate volume and whether or not the tree is alive or dead. This data is needed for each tree (if doing a full inventory) or a random sampling of trees. At a minimum, the trees need to be measured every 5 years to ensure that the growth pattern matches that of the projected tree growth. Projected tree growth can be estimated using the U.S. Forest Service's Tree Carbon Calculator for Urban Trees. All offsets generated using this protocol must be verified either by a third-party organization or via peer review. This depends highly on whether the offsets are meant for the voluntary market or internal use. All data and procedures must be transparent and available to the public.
Enforceable The reduction must be counted only once by a single organization and then retired.	After the carbon offsets have been calculated, each individual offset can only be used by a single organization and then retired (i.e. cannot be used again). To properly enforce ownership of offsets, a contract between the UTP Owner and the UTP Operator should state which organization(s) receives the offsets and how many offsets are to be given to the organization(s). Refer to the "Offset Ownership" section for additional information.
Real The reduction must actually have occurred and not be the result of flawed accounting.	Tree measurement data and the carbon offset calculation methodology should be transparent and made available to the public. The project manager should share the locations and information about the trees in an online mapping database or other similarly accessible and transparent resource that is available to the public and allows for visual verification.

Procedure for Determining Additionality

Additionality is the foundation for trustworthy carbon offset projects. While methods for determining additionality are a topic of debate within the offset professional community, the following offset checklist guides UTP Operators through the task of documenting additionality. This project-by-project approach to additionality requires each project to be assessed within its unique circumstances and relies on UTP Operators to support their findings with instituted policies, supporting documents, and signed agreements to maintain current levels of tree planting.

Additionality Checklist:

1) Do you have historical data for the number of trees you have planted in the past 5 years?
2) Are you or your organization bound by law, regulation, statute, or court order to plant trees in the same manner as the UTP Project?
    i. Provide explanation of any relevant required actions.
    ii. Attest via signature to the validity of your response.
3) Do implementation barriers, such as budget, staffing, capacity, knowledge gaps, local resistance, or other factors exist to limit your ability to plant trees beyond current business-as-usual levels?

    i. Provide detailed explanation of existing barriers.
    ii. Provide written support for the legitimacy of these barriers when possible.
    iii. Refer to Procedure for "Determining a Baseline" for guidance in establishing the business-as-usual scenario.

4) Can you demonstrate that the reductions and removals from your offset project are above the business-as-usual scenario?
    i. Provide explanation of the business-as-usual scenario.
    ii. Provide proof of a planting program.
5) Is your organization willing to sign an agreement that states you will minimize project leakage by maintaining efforts to pursue and obtain baseline tree planting funding?
    i. NOTE: Leakage can also diminish the staff capacity to maintain established trees due to the increase of trees planted. To account for this, it is important to establish a leakage buffer to account for any losses.
    ii. Refer to the section titled "Risk Mitigation" for additional info about leakage.

Co-Benefits of Urban Tree Plantings

In addition to the emission reductions, there are many other benefits associated with urban tree plantings. This section will highlight the categories that Duke University considers and assess the qualitative co-benefits of this type of program.

- ***Education***—Urban tree plantings could provide the following educational co-benefits:
    - Offer students an opportunity to develop a carbon offset program
    - Provide volunteering opportunities to coordinate and attend tree planting events
    - Inform community members about the benefits of an urban forest and trees
    - Help develop curriculum about the life and measurements of trees
- ***Social*—**Urban tree plantings could provide the following social co-benefits:
    - Engage local communities and neighborhood to host tree planting events
    - Create a safer walking environment by creating a barrier between cars and sidewalks
    - Reduce crime by fostering community pride and increasing foot traffic
    - Provide emotional and physiological health benefits including reduced employee sick time and faster recovery for hospital patients[5], increased life-expectancy, decreased stress levels, reduced asthma incidents, and decreased ADHD symptoms.[6]
- ***Environmental* —**Urban tree plantings could provide the following environmental co-benefits:
    - Remove harmful pollutants from car exhaust from the atmosphere
    - Reduce storm water runoff through water evaporation and transpiration
    - Provide shade to buildings, leading to a reduction in energy use for cooling
    - Offer habitat and food for local animal populations

[5] https://www.naturewithin.info/UF/TreeBenefitsUK.pdf
[6] Keep Indianapolis Beautiful, Trees Improve the Environment.
http://isites.harvard.edu/fs/docs/icb.topic238238.files/C:_Documents%20and%20Settings_Don%20Bockler_Desktop_CITYgreen%20articles/Urban_Tree_Facts.pdf

- ***Economic*** – Investments in the urban forest can provide the following economic co-benefits:
  - Increase property values of homes near trees
  - Improve business traffic by encouraging people to use the sidewalks
  - Increase the longevity of roads by reducing heating/cooling fluctuations
  - Reduce building energy bills by reducing heating and cooling needs
  - Provides a high return-on-investment when ecosystem services are aggregated
- ***Scalability*****—**Urban tree plantings are among the easiest carbon offset projects to scale due to their relatively low input costs and the prevalence of existing municipal tree planting crews and initiatives.
- ***Public Relations and Partnerships***—Urban tree plantings are a highly visible community engagement project. This type of project also requires the collaboration of a variety of stakeholders from municipal employees to neighborhood associations to companies looking to engage the community in a lasting, powerful way.

Credit Ownership

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 and assume responsibility for maintenance and liability for them; 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 carbon credits within that easement, and accept ownership of those Project trees by assuming responsibility for maintenance and liability for them; or

C. Have a written and signed agreement from the landowner granting ownership to the Project Operator for the Project Duration of any credits for carbon storage or other benefits delivered by Project trees on that landowner's land, and clearly designating tree maintenance responsibility and liability to one of the participating parties.

Procedure for Determining a Baseline

This protocol will determine the project baseline, and the business-as-usual scenario for UTP Projects based upon a national baseline coupled with the fulfillment of the Additionality Checklist, within the section titled Procedure for Determining Additionality. The combination of these two components assures the project's tree planting efforts are beyond the business-as-usual scenario at a national level and that the UTP is truly additional at the zoomed-in, unique organizational perspective as well.

Apply a National Baseline: Urban tree cover is declining nationally.[7] This protocol therefore permits the use of a national baseline of declining tree cover as the business-usual-scenario for use

[7] Nowak, J. David http://www.sciencedirect.com/science/article/pii/S1618866711000999

by the UTP Operator in determining the project impact. Therefore, it can be assumed that qualifying trees planted through the use of this protocol are beyond this national baseline and do not require assessment of the UTP Project Site's standing carbon before implementation of the UTP Project occurs.

Provide a Planting Program: As stated in the Additionality Checklist provide currently active planting programs, if available. This plan for tree planting offers the most accurate assessment of future tree planting efforts in establishing the business-as-usual and baseline scenario. If no formal plan exists, provide budget information combining both tree planting funds as well as tree maintenance funds to act as a financial baseline of urban forestry effort within a given jurisdiction.

Additional Options to Determine a Baseline: Further options for determining the project baseline may be found in Appendix B and represent approaches applied by CAR's Urban Forestry Protocol. These options involve a greater time commitment from the UTP Operator but may make sense to pursue if the baseline represents a scenario in which tree cover is decreasing at a rate faster than the nationally applied baseline.

Risk Mitigation

To mitigate against the risk of project failure posed by leakage, anticipated tree mortality, human error, pests, disease, fire, natural disasters, and "acts of God," this protocol recommends two approaches: 1. the use of a conservative buffer pool, or 2. bundling offsets.

Buffer Pool
A conservative buffer pool is used to protect against unavoidable reversals in the project. This buffer pool addresses three primary concerns: leakage, anticipated mortality of project trees, and crediting of offsets at project initiation. Each of these concerns are addressed within the buffer pool in the following manner:

- Leakage
    - Leakage occurs when the maintenance burden on the UTP Maintainer increases to the point where tree health across the UTP Owner's sites (project & non-project trees) suffers, or when offset project funding causes a reduction in the baseline budget for urban forest management. Unmitigated leakage can increase the likelihood of tree mortality.
        - A 5% contribution to the buffer pool accounts for this burden.
        - Adjustments can be made to Leakage's contribution 10 years after project initiation. At that point, if Leakage contribution is found to be too high, offsets can be reconciled and returned to the UTP Owner.
- Anticipated Mortality
    - Urban foresters anticipate a 3-8% mortality rate on transplanted trees in North Carolina
    - In lieu of 3rd party verification, buffer pool contributions related to anticipated mortality will be a conservative 10%[8].
- Crediting

[8] https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs158.pdf

- Once the project is initiated, Project Operators cannot purchase offsets until they have been verified to have occurred.
- Once the offsets have been verified (see verification schedule below), 85% of the verified offsets can be purchased, leaving 15% in the buffer pool in case of future mortality and leakage.

The DCOI reserves the right to review the scale and scope of all buffer pool contributions during project lifetime.

This 15% buffer pool was compared to similar protocols, such as the ACR Tool for Risk Analysis and Buffer Determination V1.0. Unintentional risk factors included in this determination of project risks are outlined below and align closely with the 15% total buffer pool required above.

Financial 4%
Project Management 4%
Social/Policy 2%
Disease and Pests (no epidemic disease or infestation in area) 4%
Other natural disaster events 2%

TOTAL DEFAULT RISK FACTOR = 16%

Alternate Option for Meeting PAVER Requirements

Bundling Offsets

Bundling is a carbon offset strategy designed to decrease risk, improve flexibility, and allow UTP Operators to leverage research and academic resources for carbon offset projects while also ensuring an immediate climate impact. The overarching goal of climate neutrality agreements is to reduce global greenhouse gas emissions, but the desire to innovate and educate at the university level sometimes leads to offset co-benefits receiving higher priority than emissions reductions. The aspiration to build community resilience through innovative, high co-benefit projects is a crucial part of combating climate change, but it should not come at the expense of mitigating emissions today. Bundling takes marketable, low-cost offsets that represent real and permanent reductions, and pairs them with university led, high co-benefit projects. This process allows institutions to reap the co-benefits of offset projects while having an immediate and measurable climate impact.

Bundling combines purchased 3rd party verified offsets with innovative local projects to reduce project risk and allow universities to ensure the climate impact occurs and co-benefits are attained. By bundling, universities can both mitigate emissions globally through 3rd party verified offsets and mitigate, adapt, and provide co-benefits locally through innovative offset projects. Bundling allows us to leverage both the robustness, scale, and lower costs of 3rd party offsets and the academic, research, and local co-benefits of innovative projects.

Counting Bundled Offsets

Only retire and apply the 3rd party verified offsets from your bundle to your GHG accounting, but include co-benefits of the local project in your reporting.

Reference the Duke Carbon Offset Initiative's 'Carbon Offset Bundling' available via sustainability.duke.edu/offsets.

Quantifying Tree Carbon Sequestration

Estimates of tree carbon sequestration are based off of the United States Forest Service's CUFR Tree Carbon Calculator (CTCC). This tool incorporates age or diameter at breast height, regional climate data, and tree species to estimate biomass rates of carbon sequestration. The United States Forest Service derives its models from data from nearly 1000 urban trees and provides this tool as an excel spreadsheet. Project developers can opt to use software packages that integrate this tool into a user-friendly interface. See Appendix 2 for more information.

Project Monitoring

The purpose of project monitoring is to ensure the project trees are achieving their goals of generating offsets, sequestering atmospheric CO_2, and providing co-benefits as projected for the full project period.

Project monitoring is conducted in two phases, full inventory and annual surveys, that repeat every 5 years according to the following schedule:

Time Since Planting	Monitoring Event Type
Within 4 weeks	Full inventory
8-12 months	Full inventory
Years 1-4	Annual surveys
Year 5	Full inventory
Years 6-9	Annual surveys
Year 10	Full inventory
Years 11-14	Annual surveys
Year 15	Full inventory
Years 16-19	Annual surveys
Year 20	Full inventory
Years 21-24	Annual surveys
Year 25	Full inventory
Years 26-29	Annual surveys
Year 30	Full inventory
Years 31-34	Annual surveys
Year 35	Full inventory
Years 36-39	Annual surveys
Year 40	Full inventory

Full Inventories

Full Inventories are used to measure the growth and health of project trees. Project verifiers compare their measurements with full inventories at each verification period (see Verification Timeline) to ensure project expectations and buffer pool contributions are aligned.

The following data must be collected during each Full Inventory for each tree planted, or in accordance with representative sampling practices as detailed in the section below titled "Sampling":

- Location (must be uniquely identifiable such as GPS coordinates)

- Species of tree
- Diameter at Breast Height (DBH)
- Height or height estimate
- Health and vigor

Additional data, such as maintenance needs & site conditions, can be captured during Full Inventories depending on the availability of each city. It is recommended that opportunities to receive direct feedback on tree health be pursued by having maintenance workers perform site visits with the verifier, and by ensuring maintenance staff includes a trained forester or that maintenance staff have access to the services of a trained forester.

Full Inventories should ensure representative project data to reduce the risk of potential future reversals. If fewer than 100% of trees are to be inventoried follow the guidance provided in Appendix 2 – Sampling Methodology to fulfill representative sampling guidelines and complete the Full Inventory.

Annual Surveys

Annual Surveys are intended to identify anomalies in the growth and health of project trees and act as preventative 'check-ups' that allow UTP Operators to identify anomalies in between Full Inventories. Annual surveys reduce overall maintenance costs and further reduce project risk. The following data must be confirmed by surveying, in accordance with the sampling recommendations, the same number of trees as in a Full Inventory year during each Annual Survey:

- Does the tree still exist?
    a. It is There/Not There
    b. It is Alive/Dead

If a tree is Not There and/or Dead (a partial project reversal) the UTP Maintainer or Operator must determine the cause of the reversal, and if biologically caused, consult a trained forester either on the maintenance staff or through an established relationship to identify the cause of the reversal and ensure additional project trees will not be affected (in the case of pests/diseases, etc.). The UTP Operator and Maintainer must then assess the carbon cost of the reversal, the appropriate action needed to recover project assets from the buffer pool, and estimate the future impact on the project's estimated sequestration of carbon.

Additional data, such as Health & Vigor, maintenance needs, and site conditions, are also recommended to be gathered during Annual Surveys to ensure consistency of management practices.

Sampling

Depending on the total population (the # of trees) of the Urban Forestry project, inventorying the entire population may not be feasible. To simplify the process and reduce the total amount of work associated with inventorying large populations, this protocol recommends sampling. Assuming the sample is representative of the entire population and limited in overall bias, sampling can be a cost and time effective method of inventorying without sacrificing data quality. This protocol utilizes simple random sampling (as explained in **Appendix 2 – Sampling Methodology**) to generate a sample that is large enough *and* representative of the population, so that the data collected from the sample can be extrapolated to the entire population with statistical significance.

As mentioned in the California Air Resources Board (CARB) Urban Forestry Protocol[9], the goal of sampling is to reduce the number of samples taken as much as possible, while avoiding biased estimates. In their protocol, CARB offers explanations of several different sampling processes. The Climate Action Reserve (CAR) also offers a guidance document regarding a distinct sampling method known as "sequential sampling." This methodology samples a small portion of the population, and if the attained values fall within a range of expected values, the sampling stops. Should any values fall outside that range or bias in the sampling is detected, sampling must continue.

Monitoring Report

Monitoring Reports must be generated following all Annual Surveys and Full Inventories, also known as Monitoring Events. During each monitoring event, the data will be collected and entered into a computer-based spreadsheet or using software designed for urban forest carbon data collection. This method should have access to current project data and will be used to estimate the generation of carbon reductions within the project. The data collected in this method must be stored to a secure server and made available to project verifiers in coordination with the Verification Timeline.

In addition to data collection, the method should produce monitoring reports after each monitoring event that include the following:

- Date(s) of monitoring event: when data was collected in the field
- Names of data collectors with contact information (both phone number and email address)
- Type of monitoring event (Full Inventory or Annual Survey)
- Estimated number of hours spent on monitoring event
- Summary of data collected
- Identification of any and all reversals (tree deaths/missing trees), any and all potential near-future reversals (evidence of tree decline or disease)
- A comparison of actual and projected carbon stocks for each Full Inventory
    - If actual carbon stocks differ from projected stocks by more than 5%, the monitoring report should also include steps for adjustment (replanting of tree, reduction in available buffer, etc.)

Data, surveys and reports from every completed Monitoring Event must be made available to project verifiers during verification periods.

Verification Requirements

Verification supports the project by confirming the validity and existence of carbon offsets generated by an offset project. This section will identify the different levels of verification that are accepted under this protocol, the requirements of each verification, and the required verification timeline.

Verification Methods

There are two accepted verification methods for projects using this protocol. Below is a description

[9] See pages 25-34.

of each method.

- 3rd Party Verification
    - An organization external to project operator, UTP Owner, and urban tree planting maintainer that is accredited to ISO standards 14065 and 14064-3 and has working knowledge of this protocol.
- Peer Institution Verification (educational institutions only)
    - A peer educational institution with an individual or department possessing working knowledge of this protocol, comprehensive knowledge of PAVER requirement fulfillment, and demonstrable ability to exercise a Verification.
    - Follow guidance document provided by the Peer Review Committee (forthcoming on OffsetNetwork.org) for executing both a Desk and a Full Verification.

The following sections describe the purpose of each verification method, the steps involved, and the resulting Buffer Pool contributions.

Verification Requirements

- Project Initiation Validation - A full verification will occur after the second monitoring event (Full Inventory at 6-12 months following tree planting)
    - During this validation event, the verifier(s) are required to do the following:
        - a site visit to ensure existence of project
        - count all planted trees (per species) to ensure it matches project operators' purchase/planting list
        - verify that all necessary contracts between the project operator and UTP Owner(s) are set, to ensure that offset ownership is enforceable
        - review monitoring reports to verify that data collection was properly documented
        - review offset projection spreadsheet for accurate accounting
        - interview data collector(s) about their data collection process
- Partial Verification
    - For years when an Annual Survey was completed, the verifier is required to do the following:
        - Review monitoring report for most recent survey
        - If the monitoring report listed any tree deaths or missing trees, ensure that a trained forester was able to make a site visit to address the losses and propose management measures if deemed appropriate.
- Full Verification
    - After each Full Inventory event, the verifier is required to perform either an Onsite Verification or a Virtual-Onsite Verification as detailed below.
    - Onsite Verification:
        - Conduct a site visit to ensure existence of project
        - Count project trees to verify project operators' count
        - Verify project trees lost to removals or tree mortality
        - Review monitoring reports to verify that data collection was properly documented
        - Interview data collector(s) about their data collection process

        - Interview tree maintainers about any tree removals or major defects
        - Review offset generation spreadsheet for accurate accounting
        - Compare calculated number of generated offsets to projected number of generated offsets to determine if they fall within 5% of each other and either fulfill requirements or require reassessment of growth models
        - Ensure all offsets have been given an individual ID and that the appropriate amount of offsets have been placed within the buffer pool
    - Virtual-Onsite Verification (fulfill all of the Onsite Verification objectives with the below adjustments):
        - A site visit may take the form of a real-time live streamed video feed (through Skype, FaceTime, Google Hangouts, or other live video streaming tool)
        - The video quality must be sufficient to verify:
            - The number of trees
            - Data collection methods
- Additional Steps Required for Peer Institution Verification (in addition to fulfilling the above requirements)
    - Forthcoming on OffsetNetwork.org

Verification Timeline

Time Since Planting	Verification Event
6-12 months	Project Initiation Verification
Years 1-4	Desk Verification
Year 5	Full Verification
Years 6-9	Desk Verification
Year 10	Full Verification
Years 11-14	Desk Verification
Year 15	Full Verification
Years 16-19	Desk Verification
Year 20	Full Verification
Years 21-24	Desk Verification
Year 25	Full Verification
Years 26-29	Desk Verification
Year 30	Full Verification
Years 31-34	Desk Verification
Year 35	Full Verification
Years 36-39	Desk Verification
Year 40	Full Verification

Appendix 1 – Additional Options to Determine the Baseline Scenario

The CAR Protocol performance standard*:* The CAR performance standard statistic is the CO_2e associated with the average of tree planting data between the 50^{th} and 100^{th} percentiles over the past 5 years from entities similar to the project. The data are based on the following:

- Municipalities/Counties: Trees Per Capita.
- Educational Institutions: Trees Per Acre of maintained landscaping
- Utilities: Trees per ratepayer

Project Operators must include the performance standard level of planting, supplied by CAR[10], as their baseline calculation as described in the Quantification Guidance:

Establishing a Baseline for a Tailored Project: This is a scenario in which Project Operators and UTP Owners freely share data and program objectives. Thus, a baseline can be calculated from the UTP Owners previous five years planting data. Determine the baseline using the following steps (3 options):

Option 1:

- Obtain quantity and species of trees planted in the previous five years.
- Using the U.S. Forest Service Tree Carbon Calculator [11] calculate the projected carbon from trees planted annually as an average of the previous five years.[12]
  - o Should include necessary reductions for verified mortality[13].

Option 2:

- Obtain average annual number of trees planted over last five years.
- Use the average as a baseline. (CAR's way)

Appendix 2 – Sampling Methodology

Simple random sampling, this protocols primary sampling methodology, involves assigning each unit within the project population a unique number. Then, using statistical equation or online sample size calculation tools, sample sizes can be derived (NOTE: identify the source of the sample size statistical equation or online calculator used). To reduce the potential for biased estimates, this protocol requires minimum sampling at or beyond the below parameters:

Confidence level ≥ 95%

Confidence interval (margin of error) ≤ 4%

Based on these parameters, table A-1 displays the recommended sample size based on population ranges.

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[10] "Urban Forest Project Data" http://www.climateactionreserve.org/how/protocols/urban-forest/

[11] See: http://www.fs.fed.us/ccrc/tools/ctcc.shtml

[12] Note that not all trees planted in the urban environment will be available on the US Forest Service's carbon calculator. When a different tree is selected, please consult with the UTP Owner, urban tree expert or reference peer reviewed literature to determine if any tree on the US Forest Service list is similar to selected tree.

[13] Verified Mortality Rate: the rate at which planted trees experience mortality through first years of life.

Table A-1

Population Size	Calculated Sample Size (using parameters listed above)	Protocol Recommendation
1-100	86	100%
101-500*	273	70%
501-1000*	375	50%
1001-2000*	462	30%
2000+*	463+	500 Trees
100,000	583	500 Trees

*The second column, "Calculated Sample Size," is calculated based on the upper bound population value.

After the sample size is determined and the random numbers have been assigned to each tree, a random number generator (as are available online, or through Excel), should be used to draw numbers of individual trees within the population, through the pre-determined sample size. Then, these trees would be inventoried and represent the urban forest population.

For example, if a project manager controlled a population of 200 urban trees and needed to sample 70% of them, he or she would assign each of the trees a unique number between 1-200 and record, using GPS or other similar technology, which tree is associated with each number. Then, using applicable software, like Excel, the project manager would request 140 numbers drawn at random between the values of 1 and 200. The 140 numbers drawn would reflect the sample of trees to be inventoried. Using the GPS data, verifiers would then measure each randomly selected tree and use the compiled data to represent the population.

Appendix 3 – Inventory Methodology

Below outlines information that would be useful to collect for each tree in the program.

<table>
<tr><th>Attribute</th><th colspan="2">Description</th></tr>
<tr><td colspan="3">Site Information</td></tr>
<tr><td>Date of Site Visit</td><td colspan="2">Day/Month/Year</td></tr>
<tr><td>Inventory Personnel</td><td colspan="2">Enter the name of the inventory technicians responsible for measuring and recording data for the project trees.</td></tr>
<tr><td colspan="3">Individual Tree Information</td></tr>
<tr><td>Location of Tree</td><td colspan="2">Latitude/Longitude from GPS</td></tr>
<tr><td>Tree Species</td><td colspan="2">Select the genus and species (including specific varietal information) or species code for the tree. The species code can be found for each species using the U.S. Forest Service’s UTP OwnerRE database or within the approved data collection method.</td></tr>
<tr><td>Diameter at Breast Height (DBH) or Tree Diameter</td><td colspan="2">Measure and record diameter of all trees 3” DBH and greater to the nearest inch using either a Biltmore Stick or a diameter tape and wrapping the tree at a height of 4.5 feet from the base of the tree on the uphill side.

If a younger/smaller tree, calipers may be required for measurement. If the tree is less than 3 inches DBH, measure diameter using calipers at 12 inches above the ground line.</td></tr>
<tr><td>Tree Height</td><td colspan="2">Measure of total height (height from base of tree to top) to the nearest foot. This can be done using a clinometer or range finder for more exact estimates. Or you could create height classifications based on estimated height (such as 0-15 feet, 15-30 feet, 30-45 feet, and so on.</td></tr>
<tr><td rowspan="4">Vigor</td><td colspan="2">Provide a rating of the tree's apparent vigor. Determination of vigor based on consideration of color foliage, crown proportion and appearance, retention of leaves/needles, appearance of apical growth, length between growth whorls, and presence of cavities and fungal growth. The code is assigned base on the following classes.</td></tr>
<tr><td>1</td><td>Excellent - tree exhibits high level of vigor and no barriers (soil, light, etc.) to continued vigor. No decay or broken branches are observed.</td></tr>
<tr><td>2</td><td>Good - tree exhibits high level of vigor and some minor barriers (soil, light, etc.) to continued vigor</td></tr>
<tr><td>3</td><td>Fair - tree appears generally health. Barriers (soil, light, etc.) affect the trees vigor. Tree's crown may be smaller proportionally than in healthier areas. Decay and/or broken</td></tr>
</table>

		branches, if observed, are not likely to have negative impacts in the short term
	4	Poor - Tree appears notably unhealthy, as determined by reduced crown, presence of decay and/or broken branches and/or significant barriers to future growth. Observed problems have high likelihood of being rectified through management of said tree and trees surrounding it.
	5	Dead - No live material is observed in the tree area.

Appendix 4 – Quantification of Carbon Offsets

Trees sequester carbon in its leaves, branches, trunk, and roots throughout its life. To have an exact estimate of carbon sequestered by a single tree, you would have to remove the tree and all of its roots, dry them, and calculate the weight of the tree. However, this is not practical for an urban forest. Instead, there are less arduous estimation methods that are recommended to be employed for this protocol.

First, to identify the potential amount of carbon that can be sequestered throughout the lifetime of a project, it is recommended to use a carbon calculator. For example, a tool from the United States Forest Service (USFS) is used to estimate the lifetime carbon sequestration of a variety of tree species in 16 climate regions around the United States.[14] For each climate region, there is an associated list of 20-30 common tree species.

If you consider the "South" climate region, which includes Durham, North Carolina, species that are listed include Loblolly pine (*Pinus taeda*), Sweetgum (*Liquidambar styraciflua*), White oak (*Quercus alba*), which are all commonly found. However, these types are trees, while native, tend not to be the variety of trees that are planted in the urban environment. Instead, in the urban environment similar species or varietals are selected due to their availability or heartiness. Regardless, their estimated growth rate and carbon sequestration rates could be used as a proxy for the actual species and variety planted. Below is a table of various southeastern tree species and their estimated carbon sequestration amounts up to year 100.

		Total CO_2 Stored per Tree (in metric tons)				
Scientific Name	Common Name	Year 5	Year 10	Year 25	Year 40	Year 100
Acer rubrum	Red maple	0.07	0.22	1.56	5.19	12.69
Acer saccharinum	Silver maple	0.11	0.49	3.74	10.65	20.71
Acer saccharum	Sugar maple	0.16	0.76	3.66	7.04	13.00
Betula nigra	River birch	0.07	0.41	4.38	9.07	9.07
Cornus florida	Flowering dogwood	0.02	0.17	1.71	3.17	3.17
Ilex opaca	American holly	0.01	0.05	0.38	1.27	3.02
Juniperus virginiana	Eastern red cedar	0.03	0.14	1.10	3.16	6.46
Lagerstroemia indica	Crape myrtle	0.00	0.04	0.90	1.50	1.50
Liquidambar styraciflua	Sweetgum	0.02	0.16	2.00	6.87	17.07
Malus spp.	Apple	0.07	0.42	2.89	4.03	4.03
Magnolia grandiflora	Southern magnolia	0.01	0.06	0.72	2.81	9.64
Pinus echinata	Shortleaf pine	0.01	0.12	1.60	5.67	9.17
Pinus taeda	Loblolly pine	0.01	0.11	1.55	5.49	7.94
Prunus spp.	Plum	0.07	0.43	7.38	15.49	15.49
Prunus yedonensis	Yoshino cherry	0.12	0.93	8.56	12.54	12.54
Pyrus calleryana	Bradford pear	0.06	0.26	2.13	3.26	3.26

[14] The Center For Urban Forests' Tree Carbon Calculator (CTCC) tool can be found on the U.S. Forest Service's website (http://www.fs.usda.gov/ccrc/tools/cufr-tree-carbon-calculator-ctcc)

Quercus alba	White oak	0.04	0.25	3.02	10.81	38.52
Quercus nigra	Water oak	0.07	0.35	3.02	8.64	24.48
Quercus phellos	Willow oak	0.03	0.26	2.71	7.67	24.63
Quercus rubra	Northern red oak	0.10	0.44	3.35	9.00	24.38
Ulmus alata	Winged elm	0.07	0.84	7.65	17.77	17.77

After the potential growth and carbon sequestration rates have been identified, the actual measurement of trees will need to be conducted to verify the accuracy of the growth estimates.

As a base requirement, a tree's diameter at breast height (DBH), height, age, and general health (alive or dead) will need to be measured and tracked. Depending on other program or municipal needs, additional data can be collected such as maintenance needs, presence of diseases or fungus, or proximity to other utilities.

Using the U.S. Forest Services Urban Forests' Tree Carbon Calculator (CTCC), you can compare the height, DBH, and age that you measured/estimated to the height and DBH to the CTCC's estimates.