Urban Forestry Carbon Offset Protocol 1.1

December 15, 2016

The 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
UFO	Urban Forest Owner
UTP	Urban Tree Planting
UTPO	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 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 beginning 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.

Authors

Charles Adair, DCOI Program Manager
Jason Elliott, DCOI Program Coordinator
Alec Brown, DCOI Urban Forestry Research Assistant

Contact Information

Jason Elliott
Program Coordinator
Duke Carbon Offsets Initiative
Jason.Elliott@duke.edu
http://sustainability.duke.edu/carbon_offsets/

Protocol Description

This urban forestry carbon offset protocol ("Protocol") outlines the methodology for developing and measuring the carbon offsets 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 – the non-GHG reduction benefits of a carbon offset. Below are a few examples of co-benefits that Duke University considers when developing projects:

- ***Education***—Urban tree plantings can provide opportunities for students to develop a tree planting program, teach citizens about tree health and maintenance, help develop curriculum about trees and the benefits that they provide.
- ***Social*****—**Urban tree plantings can provide volunteering opportunities to community members, increase the physical and emotional health of citizens, and create safer places for individuals to walk.
- ***Environmental*** **—**Urban tree plantings reduce storm water runoff, absorb harmful exhaust emissions, and provide food and shelter to local animal populations.
- ***Economic*** – Urban tree plantings can reduce energy bills, increase property values, and provide relatively low-cost carbon offsets.
- ***Scalability*****—**Urban tree plantings are easily scalable due to their relatively low cost and ability to partner with local municipal governments that already have tree planting initiatives.
- ***Public Relations and Partnerships***—Urban tree plantings are a highly-visible offset project and can bring together a wide variety of stakeholders.

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.

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

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.

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 while benefitting the very community those seeking offsets reside.

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)

---

[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

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

- 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 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 Forest Owner (UFO)*** 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 Urban Forest 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 Urban Forest Owner.

- ***Urban Tree Planting (UTP) Operators*** must contract with the Urban Forest 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 Forest Owners participate in a UTP Project, the Project Operator must secure an agreement from all other Urban Forest Owners that assigns ownership of the urban forest carbon to the Project Operator.

- ***Urban Tree Planting (UTP) Maintainer*** is an entity responsible for maintaining the health of all project trees across the project timeline. Project Maintainers can be the UFO, 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:*** Project must be entirely contained in the urban area boundary, as defined by the United States Census Bureau.[4]

- ***Project Area:*** The Project Area is the geographic extent of the UTP Project. The Project Area may be made of consolidated or disaggregated polygons. A KML file or similar file must be made of the project to clearly identify the project boundaries. There are no size limits for UTP Projects. No part of the Project Area can be included if commercial harvesting of timber has occurred in the Project Area in the past 10 years.

- ***Project Commencement:*** The commencement date for a project is the date at which the UTP Operator initiates an activity that will lead to increased GHG reductions or removals with long-term security relative to the project baseline. The earliest acceptable activity that demonstrates the commencement of project activities is a formal planning process by the UTP Operator. Subsequent activities to planning, including the purchase of equipment for tree planting, site preparation, or planting trees with a plan in place, also demonstrate a project has commenced. Once a UTP Project has commenced, new plantings can occur within the Project Area throughout the Project Life.

- ***Additionality:*** The Project must yield surplus GHG emission reductions and removals that are additional to what would have occurred in the absence of a carbon offset market. The protocols 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 will accept two performance standard metrics for urban tree planting projects. The first of which is the CAR Urban Tree Planting Project Protocol. The other is designed for projects in which the urban forest owner is willing to create a tailored program with the project operator. These standards are as follows:

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

1) The CAR Protocol performance standard metrics are based on the averages of data between the 50th and 100th percentiles. 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[5], in their baseline calculations as described in the Quantification Guidance.

2) Under a tailored scenario, a performance standard baseline is based on the 5 preceding years of historical planting data. In such a scenario planting data allows an average CO_2e to be calculated via growth models of planted tree species. The performance metric must demonstrate reductions or removals above and beyond previous GHG reduction or removals using aforementioned models of UTP tree species.

- ***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, report, and undergo verification activities for 40 years following the last credit issued to the project. The timeframe of 40 years was selected due to the DCOI's belief that carbon offsets are a bridge to a time in which a lower carbon economy has taken hold. Duke University aims to achieve a reduction in emissions to near zero by the year 2050 at which point offsets will not be necessary.

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 in order for them to efficiently store as much carbon as possible. With regards to this protocol, it is required to keep the trees alive and carbon stored for at least 40 years. This is accomplished by appropriate watering, pruning, monitoring for disease or infestation, and replacement of dead trees. However, it is important to consider the nature of trees and that they are subject to a variety of stressors in the urban setting. Some of these stressors include, minimal rooting zone, poor soil quality, drastic temperature fluctuations, lack of water, and human interactions. These

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

	issues increase the likelihood of tree failure. Therefore, it is important to determine a buffer pool to take this into account. For more information on this, please read the Buffer Pool section below.
Additional The reduction would not have occurred during a business-as-usual scenario	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 it removes barriers and resulted in an increase in tree planting and a resulting increase in carbon 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 internally by program staff. This depends highly on whether the offsets are meant for a compliance market or a voluntary market. It is recommended that if offset generation is verified internally by program staff that an external organization validate the calculations for accuracy. If verified internally, 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 urban forest owner and the urban tree planting manager should state which organization(s) receives the offsets and how many offsets are to be given to the organization(s).
Real The reduction must actually occurred and not the result of flawed accounting	A baseline must be established to gauge the impact of a tree planting project. This baseline calculation methodology, the tree measurement data, and the carbon offset calculation methodology should be transparent and made available to the public. The project manager could share the locations and information about the trees in an online mapping database that is available to the public.

Procedure for Determining Additionality

The following steps are required to establish an Urban Tree Planting Project's CO_2e reductions and removals are additional:

- ***Satisfaction of Legal Requirement***: Verify that Urban Forest Owners are not bound by law, regulation, or court order to plant trees in same manner as those prescribed by the Tree Planting Project.

- ***Identify the implementation barriers***: Survey Urban Forest Owners to determine what factors are limiting their ability to plant more trees than current baseline.
- ***Removal of Barriers***: Ensure the project will remove barriers addressed by the Urban Forest Owners.
- ***Calculate a Business as Usual Scenario***: Use historical data to calculate a baseline. (See: Procedure for Determining a Baseline)
- ***Provide Proof of a Planting Program***: Following the Quantification guidance (See: Quantifying Net GHG Reductions and Removals), demonstrate that reductions and removals were above the calculated baseline
- ***Accounting for Leakage***: A concern with a municipal forest protocol is that the income from carbon offsets could result in entities that currently plant trees decreasing their effort to pursue and obtain new funding. To combat this, signed agreements that state that current organizations will not decrease their efforts to pursue and obtain baseline tree planting funds. 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.

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 with 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
- ***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
- ***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 walk on 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 and management costs. Also, it is easy to add to existing municipal tree planting 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.

Procedure for Determining a Baseline

As previously mentioned, this protocol will accept two performance standard metrics for Urban Tree Planting Projects:

The CAR Protocol performance standard*:* The CAR performance standard statistic is the CO_2e associated with the average of tree planting data between the 50th and 100th 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[6], 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 Urban Forest Owners freely share data and program objectives. Thus, a baseline can be calculated from the Urban Forest 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 [7] calculate the projected carbon from trees planted annually.[8]
- Should include necessary reductions for verified mortality[9].
- Take average of five years carbon to determine a baseline carbon level.

Option 2:

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

---

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

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

[8] 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 UFO or urban tree expert to determine if any tree on the US Forest Service list is similar to selected tree.

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

Option 3:

- Use baseline as zero and ensure no leakage with a robust leakage strategy

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 UFO's sites (project & non-project trees) suffers. Unmitigated leakage can increase the likelihood of tree mortality
    - A 4% contribution to the buffer pool accounts for this burden.
    - Adjustments can be made to Leakage's contribution 10 years following project initiation. At that point, if Leakage contribution is found to be too high, offsets can be reconciled and returned to the UFO.
- Anticipated Mortality
    - Urban foresters anticipate a 3% mortality rate on transplanted trees in North Carolina
    - In lieu of 3rd party verification, buffer pool contributions related to anticipated mortality will be 3%.
- Crediting
    - 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), 90% of the verified offsets can be purchased, leaving 10% 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.

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 sheet. Project developers can opt to use software packages that integrates 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	Data Collected
4 weeks	Full inventory	Location, Species, DBH, Height, Health & Vigor
6-12 months	Full inventory	Location, Species, DBH, Height, Health & Vigor
Years 1-4	Annual surveys	Alive/dead/missing
Year 5	Full inventory	Location, Species, DBH, Height, Health & Vigor
Years 6-9	Annual surveys	Alive/dead/missing
Year 10	Full inventory	Location, Species, DBH, Height, Health & Vigor
Years 11-14	Annual surveys	Alive/dead/missing
Year 15	Full inventory	Location, Species, DBH, Height, Health & Vigor
Years 16-19	Annual surveys	Alive/dead/missing
Year 20	Full inventory	Location, Species, DBH, Height, Health & Vigor
Years 21-24	Annual surveys	Alive/dead/missing
Year 25	Full inventory	Location, Species, DBH, Height, Health & Vigor
Years 26-29	Annual surveys	Alive/dead/missing
Year 30	Full inventory	Location, Species, DBH, Height, Health & Vigor
Years 31-34	Annual surveys	Alive/dead/missing
Year 35	Full inventory	Location, Species, DBH, Height, Health & Vigor
Years 36-39	Annual surveys	Alive/dead/missing
Year 40	Full inventory	Location, Species, DBH, Height, Health & Vigor

Full Inventories are used to measure the growth and health of project trees. Project validators compare their measurements with full inventories at each validation period (note section/table) to ensure project expectations and buffer pool contributions are aligned.

The following data must be collected during each Full inventory (see Appendix 1 for more information):

- 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 needs of each city (insert correct term there).

Full Inventories should be collected on a representative number of project trees to ensure critical data mass and to reduce the risk of potential future reversals. If fewer than 100% of trees are to be inventoried (see below table), trees will be randomly selected prior to conducting each Full

Inventory. Adhering to a random selection method every 5 years further reduces the risk of measurement bias by ensuring a larger pool of data will be collected from a reasonable number of project trees

# of Trees in Project	Percentage of trees to inventory every 5-years	Number of randomly selected trees to inventory every 5-years
0-75	100%	75
76-150	75%	57-112
151-500	65%	98-325
501-1,000	50%	250-500
1,000-2,000	35%	350-700
2,000+	25%	500+

Annual Surveys are intended to identify anomalies in the growth and health of project trees and act as preventative 'check-ups' that allow project operators to identify anomalies in between Full Inventories. They reduce overall maintenance costs to (the city) and further reduce project risk.

The following data must be confirmed by 'drive-by' survey on (the same number of trees as in above table?) during each Annual Survey:

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

Identifying a tree as Not There and/or Dead triggers a (reversal report) to (urban offsets/DCOI/Buyer). The (responsible party) must identify the cause of the reversal to ensure additional project trees will not be affected (in the case of pests/diseases, etc…), the carbon cost of reversal, the appropriate action needed to recover project assets from the buffer pool, and an analysis of how the appropriate actions will affect future buffer pool contributions.
Additional data, such as DBH, Height, Health & Vigor, maintenance needs, & site conditions, can also be captured during Annual Surveys depending on the availability of city (insert correct term there) resources.

Monitoring Report

Annual Surveys and Full Inventories are known as Monitoring Events that produce Monitoring Reports. 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 (Method). 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 accessible by project verifiers (consistency/validators?).

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 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 offset generated by an offset project. This section will identify the four different levels of verification that are accepted under this protocol, the requirements of each verification, and the required verification timeline.

Verification Methods

There are four accepted verification methods for projects using this protocol. Below is a description of each method.

- 3rd Party Verification
    - An organization external to project operator, urban forest 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 with ISO-certified supervisor (educational institutions only)
    - A peer education institution with an individual or department that is accredited to ISO standards 14065 and 14064-3 and has working knowledge of this protocol.
- Peer Institution Verification without ISO-certified supervisor (educational institutions only)
    - A peer education institution with an individual or department with working knowledge of this protocol.
- Internal Verification
    - Internally verified by an individual or department external to the project operator or urban forest owner, yet within the same organization.

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

Verification Requirements

- Project Initiation Verification - A full verification will occur after the second monitoring event (Full Inventory at 6-12 months following tree planting)
    - During this verification, 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 urban forest 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
- Desk 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, follow up with the project operator about the plan to address the loss.
- Full verification
    - After each Full Inventory, the verifier is required to do the following:
        - 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. If the two numbers are within 5%, then offsets can be disbursed.
        - Ensure all offsets have been given an individual ID and that the appropriate amount of offsets have been placed within the buffer pool.

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 – Inventory Methodology

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

Attribute	Description
Site Information	
Date of Site Visit	Day/Month/Year
Inventory Personnel	Enter the name of the inventory technicians responsible for measuring and recording data for the project trees.
Individual Tree Information	
Location of Tree	Latitude/Longitude from GPS
Tree Species	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 UFORE database or within the approved data collection method.
Diameter at Breast Height (DBH) or Tree Diameter	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.
Tree Height	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.
Vigor	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.
	1 — Excellent - tree exhibits high level of vigor and no barriers (soil, light, etc.) to continued vigor. No decay or broken branches are observed.
	2 — Good - tree exhibits high level of vigor and some minor barriers (soil, light, etc.) to continued vigor
	3 — 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

		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 2 – 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.[10] 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

[10] 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.