Carbon Monitoring Plan for the Go Zero Program

Delivered to The Conservation Fund

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Table of Contents

1.0 Background

1.1 Reforestation of bottomland hardwood forests

The Conservation Fund's Go Zero program has engaged in restoring bottomland hardwood forests at several locations, generally within or in close proximity to the Lower Mississippi Valley. Through this program, lands used for agriculture have been reforested by planting trees at several US Fish and Wildlife Service (USFWS) National Wildlife Refuges (NWR) in Kansas, Louisiana, Missouri, and Texas. All planted sites contain similar bottomland hardwood forest conditions including species composition, soils, and management regimes.

This forest carbon measurement and monitoring plan uses a stratified random sampling design to generate estimates of carbon sequestration. This plan provides a range of sampling intensities for consideration to produce estimates of forest carbon for a range of precision targets at the 95% confidence level in accord with IPCC guidance[1] referenced in the Climate, Community and Biodiversity Alliance (CCBA) standard[2] and (see Section 1.2 for more detail on reporting goals). The contents of this plan further detail the monitoring approach, standard operating procedures to complete the forest inventory, guidance on estimating biomass and carbon stocks, and procedures for quality control and data archiving. Results of the forest inventory will be used to quantify aboveground and belowground live tree biomass and provide estimates of carbon sequestered in dead wood, litter and soil of the above (and future) Go Zero reforestation projects, which are sufficient to meet CCBA's periodic verification requirements.

1.2 Objective

This monitoring plan has been developed, for current Go Zero projects, in accordance with the CCB Project Design Standards. This plan fulfills the requirement, found in Section CL3 on

[1]Intergovernmental Panel on Climate Change (IPCC). 2006. In: Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds.), 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4, Agriculture, Forestry and Other Land-use. Prepared by the National Greenhouse Gas Inventories Programme. IGES, Japan IPCC.
[2]CCBA. 2008. Climate, Community & Biodiversity Project Design Standards Second Edition. CCBA, Arlington, VA, USA.

Climate Impact Monitoring, that a "fully developed" monitoring plan be established following the "initial monitoring plan" as outlined in the project design documents:

- The Conservation Fund. 2009. Restoring a Forest Legacy at Marais des Cygnes National Wildlife Refuge. Climate, Community & Biodiversity Alliance, Arlington, VA;
- The Conservation Fund. 2009. Restoring a Legacy at Red River National Wildlife Refuge. Climate, Community & Biodiversity Alliance, Arlington, VA;
- The Conservation Fund. 2010. Restoring a Forest Legacy at Grand Cote and Lake Ophelia National Wildlife Refuges. Climate, Community & Biodiversity Alliance, Arlington, VA; and
- The Conservation Fund. 2010. Restoring a Forest Legacy at Mingo National Wildlife Refuge. Climate, Community & Biodiversity Alliance, Arlington, VA.
- The Conservation Fund. 2011. Restoring a Forest Legacy at Upper Ouachita National Wildlife Refuge. Climate, Community & Biodiversity Alliance, Arlington, VA.

This plan replaces the initial monitoring plan published in the original CCB documents listed above except for the Upper Ouachita CCB PDD. This plan also fulfills the CCB requirements for monitoring climate impacts by stipulating the carbon pools, types of measurements, the sampling method, and the frequency of measurement. To fulfill the above requirement, the monitoring plan follows general principles of carbon accounting provided in Chapter 4 of the IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

The CCB project design standard states that

> "…carbon stocks within the project area(s) [must be inventoried], using stratification by land-use or vegetation type and methods of carbon calculation (such as biomass plots, formulae, default values) from the Intergovernmental Panel on Climate Change's 2006 Guidelines for National GHG Inventories for Agriculture, Forestry and Other Land Use (IPCC 2006 GL for AFOLU) or a more robust and detailed methodology."

For this plan we reference the former, IPCC 2006 Guidelines, due to their greater flexibility as compared with CDM Afforestation/Reforestation methodologies.

The IPCC 2006 Guidelines present three general approaches for estimating emissions/removals of greenhouse gases, known as "Tiers" ranging from 1 to 3 representing increasing levels of data requirements and analytical complexity.

Tier 1 is the least rigorous, requiring no new data collection, instead relying on default values for key forest biomass parameters corresponding to broad continental forest types provided in the IPCC Emission Factor Data Base (EFDB). While acceptable for gross accounting at continental scales, the Tier 1 approach does not capture the sub-national and regional-level distributions of forest biomass. Tier 2 addresses this issue by using country and/or region specific data.

The IPCC recommends that it is good practice to use higher Tiers for the measurement of significant sources/sinks. The CCB Project Design Standards provides further guidance:

> "Direct field measurements using scientifically robust sampling must be used to measure more significant elements of the project's carbon stocks. Other data must be suitable to the project site and specific forest type".

As such, over the life of the reforestation projects, aboveground and belowground live tree carbon stocks and stock change estimates will be derived from direct measurements on plots and thus satisfy the IPCC Tier 3 highest level of accuracy criteria. Dead wood, forest floor litter, and soil carbon stock changes, which represent a smaller proportion of forest biomass, will be estimated on the basis of default estimates of accrual, (Smith et al. 2006[3],), also used by the U.S. D.O.E. 1605(b) voluntary reporting program, and conforming with IPCC Tier 2 level reporting.

Further in conformance with IPCC guidance, the monitoring plan is designed to quantify and control for uncertainty in estimates by employing sufficient sampling intensity and unbiased allocation of measurement plots such that uncertainty can be quantified with 95% confidence.

Per IPCC 2006GL guidance, the monitoring plan includes a Quality Assurance/Quality Control (QA/QC) plan to control for errors in measurement and data analysis. Application of the QA/QC plan will provide documentation and consistency in data archiving to permit efficient third-party auditing and evaluation against measurement and quantification standards over the life of monitoring.

In addition to the onsite monitoring of carbon pools, part of the monitoring of the climate impacts will involve assessing the offsite impacts (i.e. – leakage) associated with these projects. To monitor for offsite leakage and conform with the CCBA standards, the tenant farmers who operated on the Go Zero tracts will be interviewed annually for five years to assess if there are negative offsite climate impacts as a result of these projects.

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[3]Smith, J.E., L.S. Heath, K.E. Skog, and R.A. Birdsey. 2006. Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. USDA Forest Service, Northeastern Research Station. Newtown Square, PA, USA. General Technical Report NE-343.

2.0 Monitoring approach

2.1 Carbon pools

Project monitoring will measure and quantify carbon stocks in aboveground and belowground live tree biomass. Dead wood, litter and soil carbon stocks will not be monitored; changes in these pools will be determined using default values (see Section 4.2). As the planted areas mature, the trees will shed litter and create dead wood resulting in increases in these pools and the slow increase in soil carbon accretion.

Non-CO_2 greenhouse gases (GHGs) and non-biological emissions associated with the project will also not be monitored as it is conservative to ignore these pools and these pools will make up less than 5% of the impact of the project. It is conservative to ignore these pools because if these tracts were still actively farmed, the use of farm equipment and fertilizer would generate more non-CO_2 gases than the "with project" case. In the with project case, there will be fewer entries to the planted areas and no fertilizer used. In the unlikely case that future non-CO_2 GHG emissions are not less than 5% of the monitored carbon pools, these pools will be monitored by tracking the fuel used to manage these plantings. Offsite negative climate impacts will also be monitored (as discussed above). If it is deemed that there are negative offsite climate impacts greater than 5% of the project's climate impact as a direct result of this project, these impacts will also be monitored. At this time, there are no negative offsite climate impacts.

2.2 Definition and delineation of strata

Stratification reduces overall variability and improves precision, and also permits estimates to be produced for specific strata (while not at overall precision levels). The project monitoring plan stratifies the Go Zero projects by planting location (or grouped plantings); thus each CCB project is its own stratum and can be evaluated independently. Other sources of variability in biomass growth, including species composition, topography, and flood regime, for example, are more difficult to map and will not be delineated at the current time. Sample size calculations in this report reference data from across a range of site conditions and inherently take these sources of variability into account. The six strata include: Lake Ophelia NWR/Grand Cote NWR (Central Louisiana NWR Complex), Marias des Cygnes NWR, Mingo NWR, Red River NWR, Trinity River NWR (not a registered CCB project), and Upper Ouachita NWR.

2.3 Measurement frequency

In conformance with CCB verification guidance, The Conservation Fund's Go Zero plantings will be inventoried every 5 years, with the first measurement taking place in 2013 (five years after start of the earliest project, in conformance with the CCB standard). Results will be disseminated on The Conservation Fund's website.

2.4 Sampling Design

2.4.1 Plot size and configuration

The sampled population is the entire planted area. The project employs stratified random sampling. Over the life of monitoring, sample unit type, size and/or configuration may be revised in the future to ensure efficient deployment in changing stand conditions. New strata may be added and original strata may be lumped into other strata as conditions warrant as well.

2.4.2 Optimal sampling intensity

Based on analysis of the reference data available, initial sample size was calculated to produce an estimate of mean biomass with a precision of +/-10% of the mean with 95% confidence at age 20 years and beyond. This approach, basing sample size on variability of older, more stable stands, acknowledges that achieving high precision is seldom cost effective when inventorying young, highly variable, stands and that while initial uncertainty around estimates will be high, precision will steadily improve over time. The monitoring plan retains the flexibility to adjust sampling intensity in the future in response to changing expectations regarding reporting and treatment of uncertainty, as well as observed variability on the ground.

Required sampling intensity was determined using the equation for stratified random sampling with Neyman allocation (Avery and Burkhart, 1994[4]),

Using the sampling intensity resulting from the approach outlined above, expected precision of estimates for 5-year monitoring events through year 20 and beyond are expected to decrease and then remain stable.

Live tree biomass can be considered to be zero for plots less than 5 years old as trees are likely too small to measure (i.e. below 5 cm dbh). As such, strata less than 5 years old will not be inventoried and assumed to be zero, thus leading to a conservative overall estimate of forest biomass.

2.4.3 Allocation of sample plots

The sample plots were allocated at random within each stratum using the ArcGIS tool "Create Random Points".

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[4] Avery, T.E. and H.E. Burkhart. 1994. Forest Measurements. Fourth Edition. McGraw Hill, Boston, Massachusetts, USA. 408 pp.

Sample plots will be permanently monumented at the first monitoring event to serve if needed as Continuous Forest Inventory (CFI) plots on which change in stocks can be directly tracked via future re-measurement. Establishing permanent plot markers is recommended to allow for a variety of monitoring options in the future, of particular value considering the rapid evolution of carbon accounting standards, as well as facilitate on-site audits at verification.

2.4.4 Future plantings

The Go Zero program anticipates continuing to add new tree plantings to their portfolio of reforestation projects, and therefore the overall population size will increase over time. Prior to each five year monitoring event, any new projects established since the last monitoring event will be incorporated into the monitoring population as new strata. The new strata will be delineated and new plots allocated to each based on the size of the strata and the expected variability of the strata.

3.0 Standard operating procedures

Measurement protocols to be used in the measurement and monitoring plan employ standard forest biometric practices and were developed referencing Avery and Burkhart (1994).

3.1 Establishment of measurement plots

Once a plot center location is reached, the plot will be marked by hammering a 1 cm diameter metal rebar into the ground. The metal rebar should be approximately five feet in length with about 24” of rebar (or until secure) going into the ground. A 4-foot length of PVC pipe (with internal diameter > 1 cm) should be placed over the rebar and hammered into the ground. An aluminum tag, labeled with a unique monitoring plot identification name, should be placed inside the PVC pipe for all permanent sampling plots. Finally, a PVC end cap should be placed on top end of the PVC pipe.

Coordinates of each sample plot will be recorded, when altered from original (i.e. allocated) location, with GPS to facilitate future relocation.

3.2 Layout of measurement plots

The slope of each monitoring plot (both permanent and temporary plots) should be taken and recorded. The slope will be recorded so the plot radii in the direction of the slope can later be adjusted to calculate the equivalent horizontal area.

3.3 Measurement of live trees

Within each sampling plot all stems $\geq$ 5 cm dbh will be measured. Diameter of all trees will be measured at breast height (1.3 m above ground level, see Figure 3.1). Diameter of trees with buttresses (e.g. baldcypress, water tupelo) will be measured directly above the point of termination of the buttress.

To avoid either missed trees or double recording, the point of initiation of measurement will be marked (usually due North). The first tree should be flagged and measurement should proceed in a consistent clockwise or counter-clockwise fashion.

3.4 Measuring distance

If sonic measuring equipment, such as Haglof DMEs, is to be used in the field (to check plot radii and borderline trees) they will be calibrated before each use and allowed 10+ minutes prior to use to equilibrate the unit to ambient conditions.

3.5 Boundary Issues

It is expected that boundary issues will be encountered at some plots in the field. Plots that overlap the project boundary ("boundary overlap") will be corrected using the mirage method[5, 6]

[5]Avery, T.E. and H.E. Burkhart. 1994. Forest Measurements. Fourth Edition. McGraw Hill, Boston, Massachusetts, USA. 408 pp.
[6]Ducey, M.J., J.H. Gove, and H.T. Valentine. 2004. A Walkthrough Solution to the Boundary Overlap Problem. Forest Science, 50: 427-435.

4.0

Estimates of biomass and carbon

Field measurements will be used to estimate biomass stocks in live above and belowground trees. Aboveground and belowground live tree biomass will be estimated from dbh and species group applying equations derived by Jenkins et al.[7], or other more robust allometric models that may become available in the future.

Smith et al., (2006) provides default estimates of carbon sequestered in dead wood, litter and soil.

4.1 Live tree biomass

Field data (see datasheet, Appendix C), including the diameter at breast height and common name (referable to species or genus level) of trees, will be used to generate estimates of aboveground biomass and belowground biomass and ultimately carbon stocks using allometric equations developed by Jenkins et al. 2003.

Belowground biomass is calculated by multiplying the coarse root ratio by the aboveground biomass. Terms in the equations are defined in Table 4.1. Biomass estimates will be converted to carbon stocks using a carbon fraction of 0.47, as stipulated in IPCC GL 2006.

Table 4.1. Data and parameters used for monitoring and reporting project activity.

Parameter	**Data**	**Data unit**	**Measured, calculated, default, other**	**Measurement frequency (if measured)**	**Source of data**
Dbh	Diameter at breast height of tree	cm	Measured	Every 5 years	Directly measured in permanent sample plots
bm	total aboveground biomass for trees, bm = Exp(β_0 + β_1 *ln(dbh))	kg	Calculated		Jenkins et al. 2003
β_0	parameter	dimensionless	Default		Jenkins et al. 2003
β_1	parameter	dimensionless	Default		Jenkins et al.

[7] Jenkins, J. C., Chojnacky, D. C., Heath, L. S. and R. A. Birdsey. 2003. National-scale biomass estimators for United States tree species. Forest Science 49:12-35.

					2003
R	root to shoot ratio, $R = EXP[\alpha_o + (\alpha_1/dbh)]$	$t\ C\ t^{-1}\ C$	Calculated		Jenkins et al. 2003
α_o	parameter	dimensionless	Default		Jenkins et al. 2003
α_1	parameter	dimensionless	Default		Jenkins et al. 2003

Jenkins, J. C., Chojnacky, D. C., Heath, L. S. and R. A. Birdsey. 2003. National-scale biomass estimators for United States tree species. Forest Science 49:12-35.

Table 4.2. Common names of LMV bottomland hardwood and associated tree species.

Common Name (as identified in inventory)	**Species Name**	**Species Group/Equation (Jenkins et al 2003)**
Ash	*Fraxinus spp.*	Mixed hardwood
Baldcypress	*Taxodium distichum*	Cedar/larch
Box Elder	*Acer negundo*	Soft maple/birch
Bitter Pecan	*Carya aquatica*	Hard maple/oak/hickory/beech
Black cherry	*Prunus serotina*	Mixed hardwood
Cottonwood	*Populus deltoides*	Aspen/alder/cottonwood/willow
Elm	*Ulmus spp.*	Mixed hardwood
Hackberry	*Celtis spp.*	Mixed hardwood
Hawthorne	*Crataegus spp.*	Mixed hardwood
Honey Locust	*Gleditsia triacanthos*	Mixed hardwood
Maple	*Acer spp.*	Soft maple/birch
Oak	*Quercus spp.*	Hard maple/oak/hickory/beech
Pecan	*Carya illinoinensis*	Hard maple/oak/hickory/beech
Persimmon	*Diospyros virginiana*	Mixed hardwood
Pine	*Pinus spp.*	Pine
Red Cedar	*Juniperus virginiana*	Cedar/larch
Sumac	*Rhus spp.*	Mixed hardwood
Sweetgum	*Liquidambar styraciflua*	Mixed hardwood
Sycamore	*Platanus occidentalis*	Mixed hardwood
Tupelo	*Nyssa spp*	Mixed hardwood
Willow	*Salix spp.*	Aspen/alder/cottonwood/willow

4.2 Estimates of dead wood, litter, and soil carbon

Default estimates of forest biomass and soil carbon are based on a region, ecosystem, and establishment practice specific growth and yield model (Smith et al., 2006, adapted from Table B49). These estimates are applied for all parcels of a certain age. Table B49 refers to the Oak/Gum/Cypress US Forest Service Forest Type Group. This table is used because the forest types that make up this group match well with the trees planted in the Go Zero projects[8,9].

[8] See the CCBA Project Design Documents referenced in the beginning of this document for a complete list of the species planted.
[9] B. Ruefenacht et al., "Conterminous U.S. and Alaska Forest Type Mapping Using Forest Inventory and Analysis Data," *Photogrammetric Engineering & Remote Sensing* 74, no. 11 (November 2008): 1379-1388.

5.0 Quality control and data archiving

Implementation of the monitoring plan will apply QA/QC procedures as outlined here to minimize errors in measurement and data analysis, and to provide documentation and consistency in data archiving. This section covers procedures for: (1) collecting reliable field measurements, (2) documenting data entry and analysis techniques and (3) data maintenance and archiving.

5.1 Field measurements

Field crews will be fully trained in all aspects of the field data collection and adhere to field measurement protocols. Field crew leaders will be responsible for ensuring that field protocols are followed to ensure accurate and consistent measurement. Pilot sample plots shall be measured before the initiation of formal measurements to appraise field crews and identify and correct any errors in field measurements. To ensure accurate measurements, the height of diameter at breast height (1.3 m) will be periodically re-assessed by personnel during the course of the inventory. Rangefinders will be calibrated before each use. Field crews will have fine scale parcel maps for use in the field to precisely interpret parcel boundaries and identify potential areas of plot overlap.

Throughout field monitoring events, a consistency check of an opportunistic sample of 5-10 plots shall be re-measured to identify and correct any field measurement issues which arise during implementation of the monitoring plan. Re-measurement for this purpose shall be done by different field personnel. These internal check cruises will also serve to quantify measurement error. Measurement error will be assessed as 1/2 of the mean (absolute) percent difference between re-measured plot level biomass estimates (a valid assumption where teams are equally experienced and there are no systematic errors in measurement, which will also be appraised from the re-measurement results).

During monitoring events, copies of field data sheets from previous inventories should accompany field teams so that they can verify new trees that have grown into the plots (in-growth), existing trees, and any mortality that has occurred.

5.2 Data entry

Data will be recorded on field sheets and then transcribed to electronic media. To minimize errors in data entry, where they are not the same, personnel involved in data entry and analysis will consult with personnel involved in measurement to clarify any anomalous values or ambiguities in transcription. A subset of the field sheets will be checked to ensure that data transcribed to electronic media is consistent with data on the field sheets. Database searches will be made following data entry to identify any anomalous values that require clarification or correction.

5.3 Data archiving

Because of the long-term objective of the monitoring plan, data archiving is essential. Field measurement data will be recorded on field sheets, which shall be duplicated and archived. Field data will be entered in an electronic database; data entry shall work with photocopies, not originals, to avoid loss of data. Copies of all raw data, reports of analysis and supporting spreadsheets will be stored in a dedicated long-term electronic archive. The electronic database will also archive GIS coverages detailing parcel boundaries and plot locations.

Given the extended timeframe and the pace of production of updated versions of software and new hardware for storing data, electronic files will be updated periodically or converted to a format accessible to future software applications. Adherence to these procedures will also ensure smooth transitions and maintain “institutional memory” in the event of changes in personnel responsible for the monitoring plan.