Best Practices for Including Carbon Sinks in Greenhouse Gas Inventories

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ABSTRACT
There is growing interest and urgency in quantifying the storage capacity of carbon sinks for inclusion in greenhouse gas (GHG) emissions inventories because of the need to quantify and reduce an organization's carbon footprint. This is especially critical for entities with large areas of forested land, such as public agencies and land-based private companies, as the potentially significant amount of carbon dioxide removed from the atmosphere could be accounted for as a net reduction in an organization's annual GHG emissions. Although there are relatively few examples to draw from for incorporating forest carbon sinks in an organizational level GHG emissions inventory, this paper provides timely guidance and concrete examples in the following three areas: best practices for calculating carbon sinks, recent developments in carbon sink guidance and U.S. reporting programs, and recommendations for including carbon sinks in an organizational GHG emissions inventory.

Recent developments in U.S. GHG reporting programs are critical for considering if and how to include forest carbon sinks in an organizational level emissions inventory. This paper includes a review of the latest emissions inventory guidance in the IPCC *Good Practice Guidance for Land Use, Land Use Change and Forestry*, the GHG Protocol's *Land Use, Land-Use Change, and Forestry (LULUCF) Guidance for GHG Project Accounting*, ICLEI-Local Governments for Sustainability's *Urban Forestry Toolkit*, and the California Climate Action Registry and Chicago Climate Exchange requirements for emissions reduction forestry projects.

INTRODUCTION
Greenhouse gas (GHG) emissions accounting is an area of growing interest and concern for public agency and private organization managers because of the expanding opportunities in emissions reporting and GHG emission registries, the potential for carbon offsets production, and the growing pressure for GHG accountability in the public sector. Although it is quickly becoming more streamlined and standardized, the practice of GHG emissions accounting and reporting in the U.S. is still plagued with inconsistencies due to the variety of emerging policies and programs in different jurisdictions, and the disparity in reporting requirements for different public and private programs.

Carbon sequestration is the process of incorporating atmospheric carbon into plants, soils, and water. Those resources or processes that incorporate atmospheric carbon are commonly referred to as "carbon sinks" because of their ability to take up, as opposed to emit, GHG emissions. However, carbon sequestration calculations can be difficult to perform, due to data requirements, complexity of estimation methodologies and uncertainties. Many factors, including geographic location, temperature, humidity, and species dominance, will affect the rate of carbon sequestered by forested land in a given area. The calculation of affects impacting factors, but not directly connected with the carbon cycle or GHG effects, presents an additional level of complexity

This paper on GHG emissions accounting provides an overview of accounting and reporting protocols for emissions inventories that may include carbon sinks; a review of carbon sinks and recommendations

for calculating carbon capture from biological sequestration; and insights into emerging standards and practices for carbon sinks reporting.

STANDARDS, PROTOCOLS AND PRINCIPLES

The current practice of GHG emissions accounting is guided by two main sources of standards and protocols:

- The Greenhouse Gas Protocol (GHG Protocol) of the World Resources Institute (WRI) and the World Business Council on Sustainable Development (WBCSD); and
- The technical reports and methodology guidelines of the Intergovernmental Panel on Climate Change (IPCC).

Although several programs for reporting, registering and trading emissions exist throughout the U.S. and abroad, they are mainly based on the standards and protocols of the GHG Protocol and IPCC guidelines, which are widely accepted as best practice in GHG emissions accounting. A third standard which is specific to cities and municipal agencies was developed by ICLEI-Local Governments for Sustainability (ICLEI).

In April 2007, the USEPA released an inventory of U.S. GHG emission inventories and sinks for 1990 through 2005 (the U.S. national GHG inventory). The inventory makes use of the IPCC guidelines including the updates presented in *2006 Guidelines for National Greenhouse Gas Inventories.* The inventory developed included a key category analysis for the Inventory which was consistent with IPCC's LULUCF guidelines for a Tier 1 approach. This analysis looks at prioritized sink/source categories considered to be a significant influence on the total national inventory either in terms of emissions or trends in emissions. The Tier 1 analysis quantitatively identifies key categories from LULUCF categories as well as other, while qualitatively assessment of source categories not captured in the quantitative analysis.

Accounting and Reporting Principles

According to the Corporate GHG Accounting and Reporting Module (WRI/WBCSD March 2004), the following principles should be applied to the process of accounting for and reporting GHG emissions:

- "Relevance - Ensure the GHG inventory appropriately reflects the GHG emissions of the organization and serves the decision-making needs of users – both internal and external to the organization;
- "Completeness - Account for and report on all GHG emission sources and activities within the chosen inventory boundary. Disclose and justify any specific exclusions;
- "Consistency - Use consistent methodologies to allow for meaningful comparisons of emissions over time. Transparently document any changes to the data, inventory boundary, methods, or any other relevant factors in the time series;
- "Transparency - Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used; and
- "Accuracy - Ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Achieve sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information."

The GHG Protocol
The GHG Protocol is the pre-eminent standard for conducting a GHG emissions inventory. Launched in 1998, the GHG Protocol is a multi-stakeholder partnership of businesses, non-governmental organizations, governments, academics and others convened under WRI and WBCSD. Its mission is to develop and promote broad adoption of internationally accepted GHG accounting and reporting standards and protocols.

The GHG Protocol Initiative provides two reference documents as well as a set of tools for all corporations and other organizations to identify, calculate, and report GHG emissions based on the same set of standards. The GHG Protocol has been successful in establishing the "gold standard" in emissions inventories, and has guided the development of regulatory and voluntary GHG reporting and trading programs around the world. Most programs base their accounting and reporting requirements on the GHG Protocol including, but not limited to, the California Climate Action Registry, the Eastern Climate Registry (formerly known as the Regional Greenhouse Gas Registry) the EU Emissions Trading Scheme, the Chicago Climate Exchange, and the U.S. EPA Climate Leaders Program.

The GHG Protocol consists of two modules, or guidebooks, for developing GHG emissions inventories:

- The Corporate GHG Accounting and Reporting Module, first published in October 2001 (a revised edition published in 2004); and

- The Project GHG Accounting and Reporting Module, published in November 2005.

In addition to the two guidebooks, the GHG Protocol provides more than sixteen calculation tools that represent best practice with regard to calculating GHG emissions for specific industries and sectors. The calculation tools are consistent with the IPCC guidelines for preparing national emissions inventories.

Figure 1 summarizes the three different categories, or "scopes", of emissions under the GHG Protocol (adapted from the WRI GHG Protocol). As a general rule, data for direct emissions, including direct energy generation, wastewater treatment, travel in vehicles owned by the company/organization, fugitive GHG emissions, and landfill gas, should be reported. Indirect emissions from purchased electricity and steam are also included. GHG emissions from non-company-owned vehicles or other employee travel, waste disposal, outsourced activities, product use, and purchased materials are optional to report under most programs.

IPCC Guidelines and Methodology Reports
The IPCC was established by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) in 1988. The role of the IPCC is to provide independent assessments of the scientific, technical and socio-economic information relevant to understanding climate change, its potential impacts and options for adaptation and mitigation. These assessments are based on peer reviewed, published scientific and technical literature, compiled and reviewed by international scientific, policy and economic experts of the IPCC.

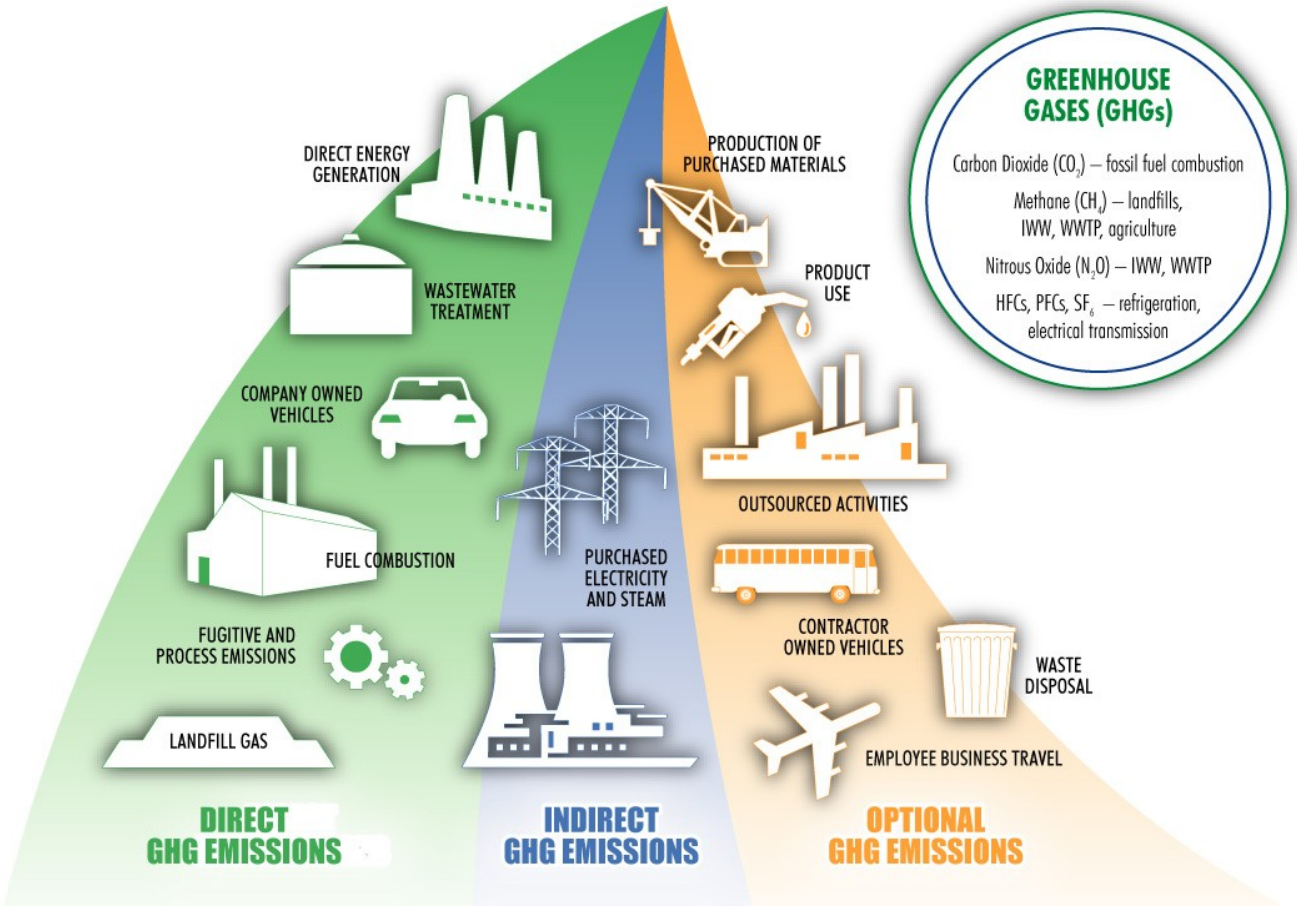

Figure 1. GHG Protocol Emissions Scopes

A main activity of the IPCC is to provide in regular intervals an assessment of the state of knowledge on climate change. The First IPCC Assessment Report was completed in 1990. The Second Assessment Report, Climate Change 1995, provided key input to the negotiations, which led to the adoption of the Kyoto Protocol in 1997. The Third Assessment Report was issued in 2001, and the Fourth Assessment Report was issued in 2007. The IPCC also prepares Special Reports and Technical Papers on topics where independent scientific information and advice is deemed necessary, and it supports the UN Framework Convention on Climate Change (UNFCCC) through its work on methodologies for National Greenhouse Gas Inventories.

IPCC Methodology Reports describe methodologies and practices for national greenhouse gas inventories and are used by Parties to the UNFCCC for preparing their national communications. The first IPCC Guidelines for National Greenhouse Gas Inventories were prepared in 1994 and revised in 1996. They are currently undergoing another major revision and new IPCC Guidelines for National Greenhouse Gas Inventories will be available in early 2007. In addition, the following Methodology Reports have been published:

- Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000);

- Good Practice Guidance for Land Use, Land-Use Change and Forestry (2003); and
- Definitions and Methodological Options related to Inventory Emissions from Direct Human-Induced 'Degradation' of Forests and 'Devegetation' of other Vegetation Types (2003).

These documents provide additional guidance for national and corporate emissions accounting, and are considered the standard worldwide for best practice in emissions inventories.

ICLEI Cities for Climate Protection ™ Campaign

ICLEI – Local Governments for Sustainability (ICLEI) is an international membership association for local governments. This non-profit organization runs the Cities for Climate Protection ™ (CCP) campaign, a program for local governments promoting greenhouse gas (GHG) emission reductions. Participants in CCP are encouraged to conduct an emissions inventory with software created specifically for local government use.

Although primarily based on the same accounting principles as the GHG Protocol and IPCC standards there are some important distinctions to note about the CCP Program:

- ICLEI emissions inventories often include the residential, commercial and transportation sectors within the agencies jurisdiction, and do not limit inventory boundaries to operational or equity control;
- The CCP emissions inventory program also includes the solid waste sector, one that is typically not included, or optional, in other accounting programs;
- Emissions factors in the ICLEI software program may differ from IPCC and GHG Protocol; and
- The CCP program is policy-based and intended to aid local decision-makers. It is not intended for GHG reporting or regulatory purposes.

CARBON SEQUESTRATION AND CARBON SINKS

Carbon sequestration is the process of incorporating atmospheric carbon into plants, soils, and water. Those resources or processes that absorb atmospheric carbon are commonly referred to as "carbon sinks" because of their ability to absorb, as opposed to emit, GHG emissions. Practices and processes that sequester carbon dioxide from the atmosphere include:

- Conservation of riparian buffers;
- Conservation tillage on croplands;
- Grazing land management;
- Afforestation;
- Reforestation;
- Forest preservation or avoided deforestation;
- Forest management;
- Underground geologic depositories; and
- Oceanic uptake.

Sequestration occurs in forests and soils primarily through photosynthesis. Carbon dioxide in the atmosphere is incorporated as fixed carbon into the roots, trunk, branches and leaves of trees, with roughly 50 percent of tree carbon storage occurring in the woody biomass (EPA 2007). The shedding of leaves does not constitute a large carbon release, as only 3% of tree carbon storage occurs in foliage, and most will be absorbed by the soil (ICLEI 2006). Carbon is released to both the soil and the atmosphere when the biomass decays. **Figure 2** shows the processes through which trees and soils gain and lose carbon. Soil carbon pools in forest lands and croplands can increase or decrease depending on inputs from plant-fixed carbon in leaves, stems and roots; human-related inputs (e.g., fertilizer); and type of management practice (e.g., conventional vs. conservation tillage) (EPA 2007a).

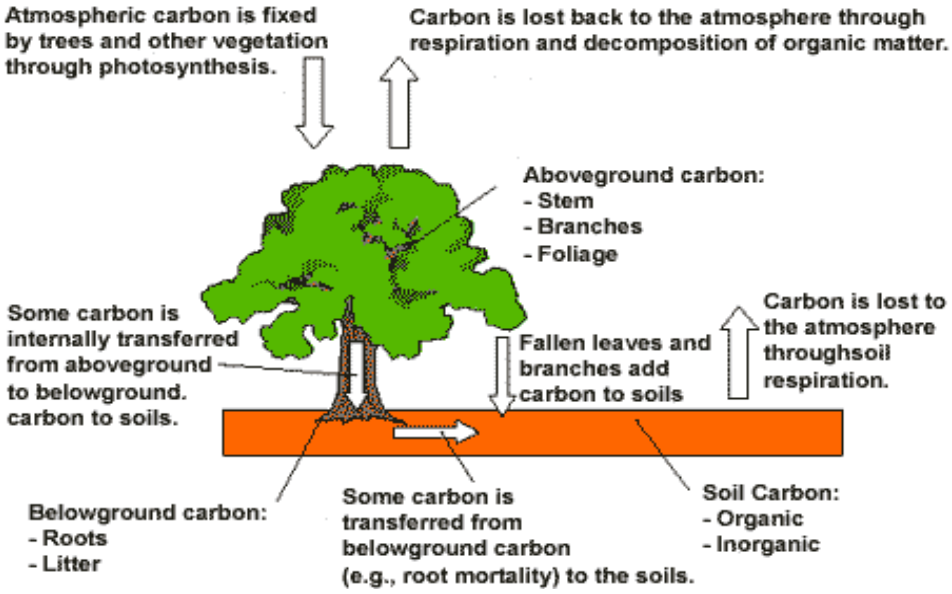

Figure 2. Carbon Sequestration in Trees and Soil. Source: EPA 2007a

Several factors affect how much carbon trees can absorb, including tree size, age and species. A mature tree can absorb up to 48 lbs of carbon dioxide a year (McAliney 1993). In fact, large trees at maturity can store approximately 1000 times more carbon dioxide than saplings (Nowak 2001). This difference highlights the importance of maintaining large tracts of healthy, mature forest, which will be much more useful in establishing carbon sinks than planting saplings. Different species of trees will also absorb different amounts of carbon dioxide (ICLEI 2006).

Another component that affects the carbon sequestration rates of forests is the amount of decomposition versus new growth occurring. If a forest is experiencing growth in the number and size of trees, it will function as a more effective sink because new growth will absorb carbon lost from decay. However, if the area of forested land is getting smaller (due to tree removal, disease, acid rain, etc.), net carbon storage will be lower, due to both a reduction of the sequestration rate, and the carbon released from tree removal and uprooting, and soil disruption.

Calculating Emissions Sinks from Forested Land

There is growing interest in quantifying the storage capacity of carbon sinks, especially in forested land area, because of the need to quantify and reduce an organization's carbon footprint. These calculations can be difficult to perform, however, as scientific investigations continue to develop and our understanding of how carbon cycles through the environment also improves. Many factors, including geographic location, temperature, humidity, and species dominance, will affect the rate of carbon sequestered by forested land in a given area.

Table 1 provides examples of different methods for carbon sequestration in forest practices, the resultant effects on greenhouse gases, and the range of carbon sequestration rates provided by EPA (EPA 2007b). Notice particularly that forests provide a very long period of carbon sequestration before becoming saturated with carbon. Secondary forests and other types of degraded forests can become effective sinks when allowed to reestablish themselves as healthy productive forestland.

In looking at Table 1, it is important to note that while this paper focuses on the calculation of carbon sequestration from forest practices, the development, management, and maintenance of forests can result in some amount of carbon sources. For example, fuel combustion and mobile emission sources associated with preparing land for planting/reforestation, or optional GHG emission estimates associated with changes in product due to forest management practices. While all these emission sources can generally, easily be mitigated through combustion fuel selections, choices of equipment used, and review of management practices, they should be considered and included when developing a complete emission inventory.

Table 1. Methods and Rates for Carbon Sequestration in Forests. Source: EPA 2007b

Key Forestry Practices	**Typical definition and some examples**	**Effect on greenhouse gases**	**Carbon sequestration rate in U.S.** Metric tons CO_2 /acre/year	**Time over which sequestration may occur before saturating**
Afforestation [a)]	Tree planting on lands previously not in forestry (e.g., conversion of marginal cropland to trees).	Increases carbon storage through sequestration.	0.6 – 2.6 [b)]	90 – 120+ years
Reforestation [c)]	Tree planting on lands that in the more recent past were in forestry, excluding the planting of trees immediately after harvest (e.g., restoring trees on severely burned lands that will demonstrably not regenerate without intervention).	Increases carbon storage through sequestration.	0.3 – 2.1 [d)]	90 – 120+ years
Forest preservation or avoided deforestation	Protection of forests that are threatened by logging or clearing for development.	Avoids CO_2 emissions via conservation of existing carbon stocks.	Based on existing carbon stock	Depends on age of existing carbon stocks
Forest management	Modification to forestry practices that produce wood products to enhance sequestration over time (e.g., lengthening the harvest-regeneration cycle, adopting low-impact logging).	Increases carbon storage by sequestration and may also avoid CO_2 emissions by altering management. May generate some N_2O emissions due to fertilization practices.	0.6 – 0.8 [e)] 0.2 [f)]	If wood products included in accounting, saturation does not necessarily occur if C continuously flows into products

Note: Any associated changes in emissions of methane (CH_4) nitrous oxide (N_2O) or fossil CO_2 not included.

a) Values are for average management of forest after being established on previous croplands or pasture.
b) Values calculated over 120-year period. Low value is for spruce-fir forest type in Lake States; high value for Douglas Fir on Pacific Coast. Soil carbon accumulation included in estimate.
c) Values are for average management of forest established after clearcut harvest.
d) Values calculated over 120-year period. Low value is for Douglas Fir in Rocky Mountains; high value for Douglas Fir in Pacific Coast. No accumulation in soil carbon is assumed.
e) Select examples, calculated over 100 years. Low value represents change from 25-year to 50-year rotation for loblolly pines in Southeast; high value is change in management regime for Douglas Fir in Pacific Northwest. Carbon in wood products included.
f) Forest management here encompasses regeneration, fertilization, choice of species and reduced forest degradation. Average estimate here is not specific to U.S., but averaged over developed countries.
g) Assumed that carbon sequestration rates are same as average rates for lands under USDA Conservation Reserve Program.

Best Practices for Carbon Sinks Accounting

Accounting for carbon sinks in emissions inventories is an evolving practice, and one with little guidance developed to date at the organizational level. This section provides an overview of the guidance and standards currently available on accounting for carbon sinks in emissions inventories, as well as a brief summary of the requirements for counting forestry projects as marketable carbon offsets.

IPCC Guidance

The IPCC's Good Practice Guidance for Land Use, Land Use Change and Forestry (LULUCF) provides guidance on estimation methodologies, quality assurance and control procedures, documentation and reporting, and quantification of uncertainties for carbon sinks accounting (IPCC 2003). This guidance is intended primarily for use in national GHG inventories as opposed to organizational level accounting. However, it provides the foundation for the estimation of GHG sinks on a smaller scale as utilized by other organizations and registries.

A preliminary element of determining carbon reductions from land use sequestration is the estimation of representative land use areas. Only broad descriptions are provided by IPCC as it is assumed each nation will use its own land use subcategories. The broad categories include forest land, crop land, grassland, wetlands, settlements, and "other". The main focus of this estimation is to determine the change in land uses over time. The actual estimation of GHG emissions sequestered or emitted is based on the following in relation to the land use categories defined by the nation or organization:

- Carbon assessments are done by the broad land use categories listed above;
- Uncertainties are also estimated and minimized where possible; and
- All emissions and calculations are reported and archived per the guidelines proved and quality control/assurance checks are implemented.

The first order approximations are calculated using **Equation 1**:

$$\Delta C = \sum_{ijk} \left[A_{ijk} \bullet \left(C_I - C_L \right)_{ijk} \right]$$

Where: ΔC = carbon stock change in the pool (tons of Carbon/year)

A = Area of Land (ha)

ijk = corresponds to climate type i, forest type j, management practice k, etc.

C_I = rate of gain of carbon (tonnes C ha-1 yr-1)

C_L = rate of loss of carbon (tonnes C ha-1 yr-1)

Additional information on quantification of carbon sinks associated with wetlands, cropland, grasslands, and other land uses can be found in Chapter 3 of the IPCC Good Practice Guidance for LULUCF (IPCC 2003).

GHG Protocol Guidance

The GHG Protocol provides guidance for organizational level inventory and reduction project accounting. The Land Use, Land-Use Change, and Forestry (LULUCF) Guidance for GHG Project Accounting (WRI/WBCSD 2006) was recently developed by the GHG Protocol to supplement existing guidance on project accounting. This document provides more specific guidance and uses more

appropriate terminology and concepts to quantify and report GHG reductions from LULUCF project activities.

The LULUCF guidance document focuses on reforestation and forest management, and can be used for avoided deforestation project activities, although they are not explicitly discussed. The main components of carbon sinks accounting that are relevant for inventories at the entity level as provided in this document are summarized briefly below:

- Defining the assessment boundary: carbon sinks under the operational control and ownership of the organization should be included in the assessment. The significance of secondary effects should be determined at this step, such as emissions from fertilizer use in afforestation projects.

- Selecting a baseline procedure: project-specific or performance based procedure should be selected, depending on the data available.

- Identifying the baseline candidates: identify alternative land uses or management practices on forestlands in a specific geographic region in a given temporal range.

- Estimating the baseline GHG removals: account for the carbon stocks, the change in carbon stocks and the GHG removals associated with the baseline scenario.

- Applying a land use or management trend factor: estimate the rate at which land-use or management changes are occurring.

- Estimating and quantifying carbon stocks: identify living biomass, dead organic matter and soils to measure, and quantify through direct measurement, default values, or modeling.

- Monitoring and quantifying GHG reductions: to ensure that carbon sequestration is taking place, develop a monitoring and verification plan.

- Carbon reversibility management: intentional (harvesting) and unintentional activities (forest fires) can alter carbon stocks, and should be considered in management planning.

- Reporting GHG reductions and net carbon stocks: reporting requirements differ by program, and should be considered in developing data management and verification procedures.

<u>ICLEI Urban Forestry Toolkit</u>

The ICLEI CACP software for emissions inventories does not include a module for carbon sinks accounting, nor do they generally advise on including carbon sinks in a municipal emissions inventory. However, given the increased amount of interest from their local government members in including carbon sequestration in their carbon footprints and GHG reduction analysis, they recently developed guidance on this issue.

ICLEI's "Protocol for Including Urban Forestry in an Emissions Reduction Plan" focuses primarily on urban trees, or street trees, but can be applied to basic forestry sink accounting practices (ICLEI 2006). This document provides guidance on incorporating both the direct carbon dioxide sequestration and ambient climatic effects that shade, solar energy reflection and transpiration have on energy use in an emissions inventory and reduction plan. ICLEI recommends including these emissions as "other" emissions, outside of the sectors normally included.

The Climate Registry

The Multi-State Climate Registry (MSCR), now known as The Climate Registry, is a new organization in development to provide a GHG registry for voluntary and mandatory GHG reporting, based on the combined interest of over thirty states and organizations including the California Climate Action Registry. According to a recently released work plan, the MSCR is anticipating a late 2007 launch date (Multi-State Climate Registry 2006). In a departure from existing U.S. based reporting programs at the organizational level, the MSCR has already indicated their intent to require the inclusion of carbon sinks in their GHG accounting and reporting program:

> "There is significant state/tribe interest in developing a rigorous accounting framework that could also quantify and characterize CO2 removals from the atmosphere. These removals, or sinks, might include terrestrial sequestration activities (e.g. forest or agricultural soil based activities) as well as geologic sequestration. The Multi-State Climate Registry would develop a comprehensive framework for accounting and reporting for sink activities, from both a project and entity approach, as soon as reasonably feasible during implementation." (Multi-State Climate Registry 2006)

Carbon Offsets

A carbon offset is a marketable commodity that represents the reduction in GHG emissions from a specific project undertaken by an organization. In order to be considered as a "carbon offset" project, a project must meet the criteria of *additionality*. Although subject to interpretation, additionality is defined by the GHG Protocol (WRI/WBCSD 2004) as "a criterion for assessing whether a project has resulted in GHG emission reductions or removals in addition to what would have occurred in its absence." Installing energy-saving light fixtures, adopting fuel-reduction protocols, or permanently protecting forestland for the express purpose of carbon sequestration would all be examples of *additional* measures an organization could take to reduce its carbon footprint.

Currently, the California Climate Action Registry (CCAR) accepts three types of forest projects as GHG reduction projects, including conservation-based forest management, reforestation, and conservation, or preventing the loss of forests to land use changes. Similar to other methodologies and requirements, the project must show long-term commitment to sustaining and maintaining the forest lands in order to qualify under CCAR. Also similar, what can be "counted" are those benefits in addition to the baseline or regulatory requirements already in place. For example, for a conservation project, the project must show there is no existing law or permit already requiring or allowing conservation of the proposed project area. On-going monitoring would be required to show the area has been protected.

The Chicago Climate Exchange (CCX) has also established rules and guidelines for estimating and issuing of carbon offsets, or Carbon Financial Instruments (CFI™), for forest carbon sequestering. CCX has grouped eligible projects into three types: forestation and forest enrichment; combined forestation and forest conservation projects in specified regions; and urban tree planting. Key elements of project eligibility include:

- As with other emission reductions associated with CCX, eligible projects include those initiated on or after January 1, 1990; and
- Projects must show long-term commitment and sustainability.

Actual CFI™ offsets earned are estimated based on the annual increase in carbon stocks during the CCX program years (2003 through 2010). Offset quantification methodologies vary based on the project size:

- For small to medium forestation projects, carbon accumulation is estimated using carbon accumulation tables or use of direct, in-field measurement and sampling; and

- For large forestation projects, carbon accumulation is estimated using direct, in-field measurement and sampling or parameterized growth models.

CONCLUSIONS

Due to the potentially large amount of carbon dioxide sequestered by forested land acquired, maintained and managed by a variety of U.S. entities, it is recommended that these organizations consider including carbon sequestration from land acquisition activities in their emissions inventory and management planning. Several items to consider before moving forward with conducting a carbon sinks inventory and GHG management planning include:

- Data requirements can be extensive and include the location and size of forested properties, species composition, forest age, estimates of forest cover; and any management practices employed.

- Given the emerging practices and opportunities for reporting, it is very important that organizations follow the most up-to-date guidelines for carbon sinks accounting. Specifically, pay close attention to The Climate Registry as they intend to develop protocols for incorporating carbon sinks in annual emissions accounting; and

- Additional information and a detailed inventory of forested land will be required in order to prepare accurate, current sequestration rates and emission sinks calculations.

Although currently limited to national inventories and forestry organizations, more and more organizations will be attempting to report their carbon sinks as a component of annual GHG emissions inventories, and managing those emissions to maximize net emissions reductions over time.

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KEYWORDS
Greenhouse gas emissions
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