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A Critical Comparison and Virtual "Field Test" of Forest Management Carbon Offset Protocols

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Table of Contents

EXECUTIVE SUMMARY

The term *offset* describes a reduction in emissions or increase in sequestration of greenhouse gases (GHG) produced by one entity that is used to compensate for emissions produced by another entity. Offsets are a key component of numerous climate policy initiatives currently under discussion or consideration. Including offsets in a GHG cap-and-trade policy framework can lower the overall cost of compliance because offsets can often be achieved at lower costs than comparably sized reductions in emissions from regulated facilities.

Regardless of how offsets are achieved, accounting for the net GHG mitigation benefit produced by an activity is absolutely critical. Numerous approaches have been developed under voluntary, regional, and international markets to account for the mitigation achieved by various offset activities. This diversity in approach has made the early carbon market a valuable source of innovation and test bed for carbon accounting concepts and methodologies, but has created a great deal of uncertainty in practice. This is especially true for forest management offsets, where accounting methodology development and implementation remain relatively nascent.

To provide the confidence necessary for the political acceptance of offsets in new mandatory policies and the continued acceptance of offsets by the buyers, a standardization of carbon accounting methodology is needed. An analysis of the lessons offered by existing forest management protocols is a key first step in this standardization process. The analysis that follows addresses this critical research gap by conducting side-by-side trials of seven existing forest management offset protocols:

- U.S. Department of Energy (DOE) 1605(b) Technical Guidelines for Voluntary Reporting of Greenhouse Gases;
- Georgia Forestry Commission (GFC) Carbon Sequestration Registry Protocol;
- Chicago Climate Exchange (CCX) Sustainably Managed Forests/Long-Lived Wood Products Protocols;
- California Climate Action Registry (CCAR) Forest Project Protocol;
- Voluntary Carbon Standard (VCS) Improved Forest Management Protocol;
- a forest management protocol derived from recommended concepts and provisions in Duke University's *Harnessing Farms and Forests in the Low-Carbon Economy* (HFF); and
- a draft recommendation for active forest management offset projects proposed by the State of Maine for inclusion under the Regional Greenhouse Gas Initiative (RGGI).

Because several years of in-field measurement and monitoring would be needed to generate enough data to allow for the critical comparisons contained herein, we use carbon sequestration data from the Calhoun Experimental Forest in South Carolina. The Calhoun Experimental Forest is one of the world's longest running forest-ecosystem studies including aboveground and belowground observations. Through it, we can draw upon five decades of in-field measurement and monitoring of whole-ecosystem carbon sequestration in our comparison of protocols.

Our virtual "field test" and subsequent analysis reveals significant differences among the seven protocols examined here. In particular, we note that two general categories emerge: 1) protocols designed to provide guidance on carbon accounting and a system for registering on-site carbon sequestration, and 2) those developed for the express purpose of marketing stored carbon. We suggest that GFC and 1605(b) are more appropriately classified as the former (termed "registries"), while CCX, CCAR, VCS, HFF, and RGGI are best described as the latter ("full protocols"). Depending on the approach used and the pools included, total creditable carbon after 100 years of project implementation ranges from a low of 70.6 metric tons of CO_2e ha^{-1} under VCS to a high of 598.0 metric tons of CO_2e ha^{-1} under 1605(b). We also explore the carbon prices needed to match or exceed the NPV of timber-only management, but suggest that a comparison of the relative performances between protocols is potentially more informative than absolute findings of profitability due to assumptions made herein.

The significant variations in the amount of creditable carbon generated under each methodology stem from differences in the scope and stringency of carbon accounting techniques. In particular, the choice of baseline methodology and the choice of which pools to include strongly influence the amount of creditable carbon generated by the project. A cohort group performance standard is the most conservative baseline approach evaluated, but it is also the most reliant on outside data. At the other end of the spectrum, we find that a "base-year" baseline approach will allow non-additional carbon to be credited under situations similar to the one modeled here. With regard to carbon pools, the Wood Products pool comprises a substantial portion of gross carbon sequestration when included. Fully accounting for the wood products that would have been produced in a business-as-usual (BAU) scenario, however, causes the Wood Products pool to become a strong, net drain on total project creditable carbon.

We find that each protocol has its own set of strengths and weaknesses. Two (1605(b), GFC) fail to address issues such as leakage and catastrophic reversal risk, but provide extensive technical information and tools that may be leveraged to assist landowners in carbon accounting. The other five protocols evaluated here provide more robust carbon accounting schemes, with most directly considering issues of leakage, reversal, and uncertainty. Mandatory buffer set-asides to address reversal risk are included or contemplated under several protocols (CCX, VCS, RGGI), as are deductions for leakage (VCS, HFF, RGGI) and uncertainty (CCX, CCAR).

Collectively, these findings can be used to highlight potential "best practice" approaches for forest management offset accounting. These approaches are selected solely on a carbon accounting perspective as informed by this report, and incorporate aspects of CCX, CCAR, VCS, HFF, and RGGI protocols. Their inclusion here provides an example of how lessons learned in state, regional, and voluntary markets can be drawn upon in the creation of a singular standard.

KEY TERMS, UNITS, AND ABBREVIATIONS

Additionality – The extent to which greenhouse gas mitigation is above and beyond what would have occurred in the absence of offset project implementation.

Baseline – The point of reference used to assess the net greenhouse gas mitigation associated with an offset project.

Buffer *or* **Reserve** – The pool of credits or allowances held in reserve in case of intentional or unintentional losses of stored carbon to the atmosphere. This is different from deductions made for uncertainty, leakage, or other purposes, as these other discounts are simply subtracted from the total amount of carbon generated.

Business-as-Usual (BAU) – The management scenario expected in the absence of offset project implementation.

Carbon Pool – A specific component of the forest biological system that is capable of both storing and releasing carbon.

Creditable Carbon – The amount of stored carbon that may be reported, registered, or claimed by the project developer. In a fully functioning carbon market, creditable carbon is the portion of gross carbon storage eligible for sale.

Leakage – An induced shift in activity or activities, resulting in a change in emissions or sequestration outside the boundaries of a particular policy, market, or entity.

1 metric ton = 1,000 kg = 2,205 lb = 1.10 short (U.S.) tons
1 hectare (ha) = 2.47 acres (ac)
1 metric ton carbon = 3.664 metric tons Carbon Dioxide Equivalents (CO_2e)

CCAR	California Climate Action Registry
CCX	Chicago Climate Exchange
FIA	U.S. Forest Service Forest Inventory and Analysis Program
GFC	Georgia Forestry Commission
GHG	Greenhouse Gas
HFF	*Harnessing Farms and Forests* (Willey and Chameides 2007)
NPV	Net Present Value
RGGI	Regional Greenhouse Gas Initiative
VCS	Voluntary Carbon Standard

INTRODUCTION

In climate change and carbon market circles the term *offset* describes a reduction in emissions or increase in sequestration of greenhouse gases (GHG) produced by one entity that is used to compensate for emissions produced by another entity. Under a mandatory GHG cap-and-trade policy the term *offset* is more specific, describing a reduction in emissions or increase in sequestration achieved by an entity outside of the compliance cap that is used to compensate for emissions produced by a capped entity. Offset projects have the potential to achieve emission reductions at lower costs than comparably sized reductions in emissions from regulated facilities. Therefore, the inclusion of offsets in a cap-and-trade policy framework can lower the overall cost of compliance by providing a pool of low-cost mitigation options (Amano and Sedjo 2006).

Offsets are created by reducing emissions or by increasing the carbon stored in trees and soils and harvested wood products. Emission reduction activities include the capturing and subsequent flaring or renewable energy use of methane generated by landfills, water treatment facilities, and animal waste. Increases in sequestration can be achieved through activities such as reforestation, improved forest management, and switching to reduced-tillage farming. Regardless of how offsets are achieved, accounting for the net GHG mitigation benefit produced by an activity is absolutely critical. This is because the GHG mitigation benefit associated with an offset can be purchased and used to compensate for increases in emissions elsewhere. Any offsets trade needs to achieve the expected environmental outcome (an overall reduction in GHGs) and provide the expected return on investment (the expected amount of GHG mitigation).

Numerous approaches have been developed to account for the mitigation achieved by offsets. In the absence of a single offsets standard, a variety of carbon offset accounting approaches have emerged. These approaches often address similar accounting issues such as baseline, additionality, and permanence, but more often than not, define them differently and establish differing ways to evaluate them. This diversity in approach has made the early carbon market a valuable source of innovation and test bed for carbon accounting concepts and methodologies (Olander 2008). This diversity has also created a great deal of uncertainty for investors and project developers. Multiple approaches for conducting offset projects can even damage the public credibility of market-based solutions (Gillenwater et al. 2007).

Many efforts are underway to build on the lessons of this early market. Some provide guideposts (see, e.g., Offsets Quality Initiative 2008) or standardized criteria and overlaying guidelines for the development of offsets protocols/methodologies (e.g., the Gold Standard,[1] the Voluntary Carbon Standard[2]). At the same time a number of regional mandatory climate programs are under development in the U.S., all of which are building or planning to build their own offsets programs based on these past efforts. And the federal government is in an accelerating process of creating a federal cap-and-trade policy in which offsets will play a critical role and build from lessons learned. Common to all of these efforts is the standardization of offset methodology. The setting of standards is critical in providing the confidence necessary for the political acceptance

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[1] See http://www.cdmgoldstandard.org/, last accessed August 11, 2008.

[2] See http://www.v-c-s.org/, last accessed August 11, 2008.

of offsets in the new mandatory policies and the continued acceptance offsets by the buyers (the community of greenhouse gas emitters).

A complicating factor in this standardization process is the difference in implementation experience between different types of offsets. Certain activities like the capture and flaring of methane from landfills have a longer track record of implementation as offsets and have more fully developed and accepted methods for accounting. In contrast, forest offset projects are subject to a wide variety of accounting and implementation hurdles (Richards and Andersson 2001). Forest management offsets in particular remain in the nascent stages of development; accounting methodologies (and the resulting environmental integrity and profitability of this methodology) are still being developed and debated. The development of accounting methodologies for forest management offset projects are complicated by the dynamic nature of carbon storage in forest systems and a lack of standardized management and land use practices across users and landscapes.

Despite these shortcomings, the sheer size of the GHG mitigation potential in the U.S. forestry sector necessitates its inclusion in any comprehensive policy solution to climate change. Forests represent a significant opportunity for GHG mitigation in the U.S. and around the world, and their inclusion in climate policy can provide social and environmental co-benefits (see, e.g., Malmsheimer et al. 2008). In recent years, U.S. forests and forest products have sequestered over 700 million metric tons of CO_2e per year (U.S. Environmental Protection Agency 2008). Given a high enough price for carbon, afforestation and forest management in the U.S. have the potential to sequester an additional 1.2 billion metric tons CO_2e per year (U.S. Environmental Protection Agency 2005).

To facilitate the standardization of forest management offset accounting procedures, we explore the differences between forest management offset accounting approaches developed to date. It remains to be seen whether differences between the protocols result in any significant differences in creditable carbon, or the amount of stored carbon that may be reported, registered, or claimed by the project developer. To rectify this critical research gap, we conduct side-by-side virtual trials of seven distinct forest management offset protocols. This paper is the first of two papers to compare and assess the forest management protocols that have been developed to date. This paper focuses on the accounting methods used and what this means for net creditable carbon. A second paper will focus on the transaction costs associated with conducting these accounting methods to better assess whether there is a trade-off between accuracy and cost, and hopefully try to find the best solution: greatest accuracy with lowest cost.

METHODS

This analysis is based on the hypothetical implementation of a forest management carbon offset project in the Piedmont region of South Carolina. The analysis compares seven offset protocols, all applied to the forest carbon database of the Calhoun Experimental Forest in South Carolina, one of the world's longest running forest ecosystem studies that includes aboveground and belowground observations. Five decades of in-field measurement and monitoring of whole-ecosystem carbon sequestration are used in this comparison.

Carbon Data Acquisition

Data on forest carbon accumulation for Southeastern loblolly pine stands is derived from carbon inventories at the Calhoun Experimental Forest in Union County, South Carolina. Primary deciduous forests at the site were cleared in the early 1800s, and the site was managed mainly for cotton and other row crops until the last crop of cotton was harvested in the mid-1950s. In 1957, sixteen 0.1-ha permanent plots were installed on two cotton fields, and loblolly pine seedlings were planted at four spacings (1.8m, 2.4m, 3.0m, and 3.7m). The research site has served as a basis for numerous long-term studies on carbon and nutrient cycling and ecosystem dynamics (e.g., Richter et al. 1999; Richter and Markewitz 2001).

In the subsequent decades since the plots were installed, tree height and diameter were measured on six separate occasions (1972, 1978, 1982, 1990, 1997, and 2005). Tree biomass was estimated by a combination of allometric equations depending on age and tree component (Nelson and Switzer 1975; Pehl et al. 1984; Shelton et al. 1984; Van Lear et al. 1986; Baldwin 1987; Kapeluck and D.H. Van Lear 1995). At stand age 34 in 1991, site-specific equations were estimated to predict aboveground biomass from the harvest and dimensional analysis of 10 trees, and foliar biomass was estimated from monthly collections of litterfall over the course of two years (Urrego 1993). Root carbon varies as a percentage of total tree biomass from less than 15% to greater than 25% (see, e.g., Richter and Markewitz 2001); here we assume that root carbon represents 15% of total tree biomass.

Mineral soil was sampled on eight occasions since plot establishment (1962, 1968, 1972, 1978, 1982, 1990, 1997, and 2005), and forest floor was sampled in 1997. Forest floor samples consisted of 30-cm-diameter samples from each of the eight plots. Mineral soil was sampled at four depths (0 to 7.5cm, 7.5 to 15cm, 15 to 35cm, and 35 to 60cm) by taking twenty 2-cm-diameter punch-tube cores and compositing samples by depth within each sample plot. Bulk density was sampled with a 6-cm-diameter core in the early 1990s (Richter et al. 1994). Nearly all soil samples are stored in an archive at Duke University.

Carbon Sequestration Modeling

Based on five decades of observations, repeated sampling, and archived samples, a spreadsheet model was created to simulate repeated 25- and 50-year clearcut harvests at the Calhoun forest. This allows us to take an ex post monitoring perspective on the hypothetical project, examining carbon sequestration as if it were actually achieved over 100 years of project implementation.

Creation of the model also allows us to generate carbon sequestration estimates under other management scenarios, which can in turn be used to estimate baseline and other components.

Despite the 50-year data record, a number of assumptions are necessary. Some of the most important are the following: (1) tree productivities were maintained rotation after rotation; (2) after logging, 10%, 15%, and 3% of tree biomass were added to the forest floor and soil as litter, coarse woody debris, and dead taproots, respectively; (3) in the mineral soil, 5%, 5%, and 1% of tree biomass were added to the A, B, and deep B/C soil horizons, respectively; and (4) post-harvest decomposition was modeled with exponential decay functions, depending on component. A detailed version of the carbon sequestration and modeling is in preparation (Mobley et al., in preparation).

In order to use the Calhoun data to simulate an offsets project under the various protocols examined in this study, pool terminology is aligned as shown in Table 1. “Biomass” includes both aboveground and belowground carbon, so 85% of the pool is allocated to Live Tree and 15% to Belowground. Within the Calhoun sample plots, carbon stored in “Seedling/Sapling” and “Herbaceous” pools is assumed to be negligible. Carbon in standing dead trees likewise represents a small contribution to total carbon storage at the Calhoun site, with snags only appearing in the final years of the 50-year data series. As a result, “Taproot Detritus” is combined with “Coarse Woody Debris” to generate estimates for any Dead Tree carbon stored on-site.

Table 1. Description of the various carbon pools examined for each protocol and the equivalent carbon pool derived from Calhoun Experimental Forest data. All pools are described in terms of metric tons C ha^{-1}.

Protocol Pool	Equivalent Calhoun Pool
Live Tree	“Biomass” x 0.85
Dead Tree	“Coarse Woody Debris” + “Taproot Detritus”
Seedling/Sapling	(negligible)
Herbaceous	(negligible)
Belowground	“Biomass” x 0.15
Litter	“O Horizon”
Soil	“A Horizon” (< 35cm), “Upper B” (35cm-60cm), and/or “B/C” (60cm–2m), depending on protocol

Protocol Implementation

There are a variety of ways to increase carbon storage in managed forests, most notably by increasing the productivity of the forest or by letting the forest grow longer. Here, we explore the implications of the latter. The hypothetical project to which the protocols are applied consists of a rotation extension from 25 to 50 years.[3] The project consists of ten 10-hectare, even-aged stands of identical composition and site quality (site index 75, base age 25), and is implemented for a period of 100 years. At project inception, there are two stands each of 0, 5, 10, 15, and 20 years old. One stand in each pair is managed on a 25-year rotation until the first harvest, and then

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[3] The decision to double rotation age here is based primarily on data availability; at the time of harvest in 2007, stands in the Calhoun Experimental Forest were 50 years old. In reality, it is unlikely that a landowner would double the rotation age of Southeastern loblolly pine. A more likely scenario is a lengthening of rotation by 5 or 10 years.

converted to a 50-year rotation. The other stand in each pair is immediately converted to a 50-year rotation. In this manner, the rotation extension is phased in over time, yielding a more consistent harvest stream.

As this analysis evaluates a change in rotation age in a conventionally managed forest, the effects of other management variables are not examined. While in reality management plan or certification requirements will likely influence the amount of creditable carbon potentially claimed, this analysis does not attempt to determine the net carbon implications of management restrictions.[4] For all protocols, it is assumed that any required forest management plans are being implemented. South Carolina Forestry Commission Best Management Practices[5] are followed at the Calhoun site, and are assumed to be followed under each of the protocols considered here.

The seven protocols evaluated are:

- U.S. Department of Energy (DOE) 1605(b) Technical Guidelines for Voluntary Reporting of Greenhouse Gases (Office of Policy and International Affairs 2007);
- Georgia Forestry Commission (GFC) Carbon Sequestration Registry Project Protocol (Georgia Forestry Commission 2007);
- Chicago Climate Exchange (CCX) Sustainably Managed Forests/Long-Lived Wood Products Protocols (Chicago Climate Exchange 2007b; Chicago Climate Exchange 2007a);
- California Climate Action Registry (CCAR) Forest Project Protocol (California Climate Action Registry 2007);
- Voluntary Carbon Standard (VCS) Improved Forest Management Protocol (Voluntary Carbon Standard 2007a; Voluntary Carbon Standard 2007b);
- a forest management protocol derived from Duke University's *Harnessing Farms and Forests in the Low-Carbon Economy* (Willey and Chameides 2007); and
- a draft recommendation for active forest management offset projects under the Regional Greenhouse Gas Initiative (RGGI) (Maine Forest Service et al. 2008).[6]

The above list is not exhaustive; other forest management offset project protocols may exist. However, the seven protocols listed above provide broad representation of the different accounting methods currently being used or considered for forest offset projects. Each of the protocols listed above also possess some degree of implementation experience, stakeholder support, or political buy-in—aspects that are likely to factor heavily into the development of a singular standard should one emerge. Owing to the state or regional nature of some of the above protocols, it is unlikely that all would be used for actual offset projects operating in the South

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[4] Some protocols (e.g., CCAR) require adherence to strict forest management regulations. Others (e.g., GFC) require that landowners implement established BMPs. Still others (e.g., CCX) require that forests be third-party certified. These various requirements have the potential to influence carbon sequestration by placing restrictions on harvest and planting behavior (e.g., the use of native species and mixed stands, maintenance of stream buffers, limitations on rotation length, etc.).

[5] An in-depth overview of South Carolina's BMPs is provided in South Carolina Forestry Commission, 2007.

[6] The protocol examined here was issued by the State of Maine in June 2008, and represents one potential method by which to include active forest management under RGGI. It has not been accepted or otherwise endorsed by RGGI. It is included here to provide an additional example of the approaches being considered for forest management carbon accounting.

Carolina Piedmont (notably CCAR and GFC). Using a common location for all seven methodologies, however, allows for direct comparison between them.

For each protocol evaluated, the carbon in required and eligible pools is tallied, baseline determined, and leakage,[7] uncertainty discounts, and reserve set-asides deducted as outlined in the relevant protocol. For accounting simplicity, discounts, buffers, or set-asides are deducted from non-negative stocks only.[8] Unless otherwise noted, carbon pools refer to the components outlined in Table 1. Protocol-specific methods, pools, and other components are summarized in Table 2. Many protocols use similar approaches to determine baseline and calculate carbon stored in wood products; a review of these approaches is provided separately below. Specific treatments or calculations are described in detail under the relevant protocol heading.

Table 2. Overview of key components of the seven protocols examined in this analysis. Protocols designed to provide guidance on carbon accounting and a system for registering carbon sequestration are classified as "registries." Those developed for the express purpose of marketing stored carbon are classified as "full protocols." "X" in the Reversal, Uncertainty, or Leakage column indicates that the protocol includes an approach for calculating and incorporating a set-aside or discount attributable to that particular component; the absence of "X" in a specific category does not imply that the protocol does not consider that component, only that there are no mechanisms to adjust creditable carbon on the basis of it. Only those pools contributing a significant amount of carbon to total stand sequestration at the Calhoun site are included; a given protocol may include more pools than those evaluated here.

Entity	Type	Baseline	Additionality	Pools Included [A]	Reversal-Uncertainty-Leakage		
1605(b)	Registry	Base-year	Base-year	🟩 🟥 ⬜ ⬛ 🟫 🟨	-	-	-
GFC	Registry	Base-year	Base-year	🟩 🟥 🟫* 🟨*	-	-	-
CCX	Full Protocol	Base-year	Base-year	🟩 🟥 🟨*	X	X	-
CCAR	Full Protocol	Single-practice Performance Standard	Regulatory	🟩 🟥 ⬜ ⬛* 🟫* 🟨*	-	X	X
VCS	Full Protocol	Single-practice Performance Standard	Regulatory, Barriers, Common Practice	🟩 🟥* ⬜* ⬛* 🟫* 🟨*	X	-	X
HFF	Full Protocol	Cohort Group Performance Standard	Cohort Group Performance Standard	🟩 🟥 ⬜ ⬛ 🟫 🟨*	-	-	X
RGGI	Full Protocol	Base-year	Regulatory, Base-year/ FIA mean	🟩 🟥 ⬜* 🟨*	X	-	X

[A] Carbon pools include: 🟩 – Live Tree; 🟥 – Belowground; ⬜ – Dead Tree; ⬛ – Litter; 🟫 – Soil; 🟨 – Wood Products. Optional pools are denoted with an asterisk.

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[7] While many of the protocols reviewed here require whole-entity reporting to address on-site leakage, our focus in this report is on those emissions resulting from activities shifted off-site or outside of the entity's control. Activity-shifting leakage within entity boundaries (on-site) is assumed to be zero for all protocols.

[8] We assume that there is no "creditable carbon" generated in those years where net sequestration is negative (gross carbon < baseline), so therefore no need for a buffer, no associated leakage, etc.

Overview of Protocols

1. U.S. DOE 1605(b)[9]

Eligible carbon pools under the 1605(b) Technical Guidelines are listed in Table 2.[10] The 1605(b) accounting methodology defines the soil ecosystem carbon component as including the top one meter of soil; only Calhoun pools "A horizon" and "Upper B" are used to estimate carbon sequestration so as not to overestimate the contribution of this pool. Baseline and additionality are determined through a **base-year** approach. Carbon stored in wood products is determined through a **100-year method**. No deduction is required for leakage or uncertainty.[11] No reserve or buffer is required to be set aside, but we assume that credits are "bought back" from the market in years of negative sequestration.

2. Georgia Forestry Commission Carbon Sequestration Registry Project Protocol[12]

Required and option pools under the Georgia protocol are listed in Table 2. The Calhoun pool "A horizon" is used to estimate soil carbon sequestration as the Georgia protocol only requires measurement of soil carbon to a depth of 12 inches. Baseline and additionality are determined through a **base-year** approach. Carbon stored in wood products is determined through a **100-year method**. No deduction is made for leakage or uncertainty. No reserve or buffer is required to be set aside, but we assume that credits are "bought back" from the market in years of negative sequestration.

3. CCX Sustainably Managed Forests/Long-Lived Wood Products Protocols

Required pools under the CCX Sustainably Managed Forest protocol are listed in Table 2. Wood Products are also included here, but are governed by a separate protocol and therefore considered to be optional. Baseline and additionality are determined through a **base-year** approach. Carbon stored in wood products is determined through a **100-year**

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[9] It is important to note that the 1605(b) Technical Guidelines are designed to provide "extensive guidance on how to calculate and report greenhouse gas emissions" (Office of Policy and International Affairs, 2007, p2). They do not comprise an official protocol *per se*, nor do they provide a market platform for carbon credit transactions. However, it is likely that an eventual national protocol will draw upon the federal experience with drafting the Technical Guidelines and implementing the voluntary reporting mechanism under which the guidelines fall. Therefore, it is appropriate to evaluate the 1605(b) accounting methodology here.

[10] For the purposes of this analysis, all pools under the 1605(b) accounting methodology are classified as "Required." While it would have been technically more appropriate to classify all pools as "Optional," this would lead to zero carbon being generated under the Required Pool scenario explored below, thus preventing comparison with the other six methodologies explored here.

[11] 1605(b) does require that reported emission reductions or increases in sequestration meet established grade requirements. This does not directly impact the rate of creditable carbon generation under this analysis, but does establish minimum project data quality standards while providing some degree of flexibility to the landowner.

[12] The GFC protocol explicitly states that the purpose of the Georgia Registry is not to provide a market platform for carbon credit transactions. Rather, the Registry is intended to "facilitate the transfer of forest offset projects to current and future carbon markets and provide an official record for offset projects undertaken in the state of Georgia" (Georgia Forestry Commission, 2007, p8). Because projects undertaken pursuant to GFC guidelines may transition into other "current and future markets" through which carbon transactions may occur, it is appropriate to evaluate the accounting here.

method. CCX requires that the minimum of 20% or two times the statistical error of baseline inventory data be deducted to account for variance in model estimates. No deduction is required for annual in-field inventories. Because modeling is used here to generate estimates for annual carbon accumulation, a sampling error of 10% of the mean is assumed, thus requiring a 20% deduction from creditable carbon in required pools. The implications of a 0% uncertainty withholding scenario are discussed later in the report under "Critical Analysis of Components and Assumptions." No deduction is required for leakage. Twenty percent of annual creditable carbon generated from Live Tree and Belowground pools is deducted as a reserve, and is assumed to remain a constant proportion relative to the project carbon stock.[13] The buffer is not drawn upon in years where emissions exceed sequestration. Instead, we assume that credits are "bought back" from the market in those years. No reserve is required for carbon stored in the Wood Products pool.

4. *CCAR Forest Project Protocol*[14]

Required and optional pools under the CCAR protocol are listed in Table 2. Under current CCAR guidelines, emissions reductions resulting from accounting of optional pools cannot be certified, and therefore cannot count as "creditable carbon" for the purposes of this study. Consequently, optional pools are excluded. It is assumed that the area in which the hypothetical project is implemented has performance standards in place to promote the "sustained production of high-quality timber products while giving consideration to values relating to recreation, watershed, wildlife, range and forage, fisheries, regional economic vitality, employment, and aesthetic enjoyment" (California Climate Action Registry 2007, p19).[15] As there are no rotation age restrictions or reforestation requirements for private forest land in South Carolina, it is also assumed that the project satisfies regulatory additionality criteria. A **single-practice performance standard,** 25-year rotation scenario projected over a 100-year project lifetime is used as a baseline. Current CCAR project guidelines do not outline a specific methodology for calculating off-site leakage, nor do they require its quantification. Off-site leakage is therefore excluded in this assessment. It is also assumed that field sampling would yield estimates of carbon with sampling errors between 5.1% and 10% of the mean at the 90% confidence level, thus requiring a 10% deduction from creditable carbon in required pools. Finally, no reserve or buffer is required to be set aside, but we assume that credits are "bought back" from the market in years of negative sequestration.

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[13] Under the Chicago Climate Exchange, any credits remaining in the buffer account may be released back to the project at the end of the accounting period. In reality this corresponds to the close of Phase 2 of the CCX program commitment period in 2010. However, to be consistent with the timelines of other protocols, it is assumed here that the project in question runs in perpetuity, and that no buffer credits are returned to the project.

[14] The CCAR protocol was not explicitly designed for implementation in the state of South Carolina, but its evaluation here provides an opportunity for direct comparison with other major protocols.

[15] The CCAR forest project protocol requires natural forest management with mixed species and multiple age classes, so it is important to note that the hypothetical project (even-aged rotations of planted loblolly) may not satisfy all CCAR eligibility criteria for managed forest projects.

5. *VCS Improved Forest Management Protocol*

Required and optional pools included under the VCS Improved Forest Management-Extended Rotation protocol are listed in Table 2.[16] The Calhoun pools "A horizon" and "Upper B" are used to estimate soil carbon sequestration. Additionality is demonstrated through a project test. As there are no rotation age restrictions or reforestation requirements for private forest land in South Carolina, it is assumed that the project satisfies regulatory surplus criteria. It is likewise assumed that common practice in the region is to manage for rotations that are shorter than 50 years.[17] Finally, it is assumed that the revenue generated from the sale of carbon credits allows for the project to be lengthened from a 25-year, maximum-sustained-yield rotation, thus overcoming investment barriers. A **single-practice performance standard,** 25-year rotation scenario is used as a baseline, as this is assumed to be "what most likely would have occurred in the absence of the project" (Voluntary Carbon Standard 2007a, p17). A **100-year method** is used to determine the fraction of carbon stored in wood products, and is estimated for both 50-year rotation and baseline scenarios.[18] Using the criteria established in the protocol, a 10% discount for leakage is chosen based on an assumption that harvests would shift across time periods, with minimal changes in total timber harvest over time. The project is assumed to be "low risk," requiring a buffer set-aside of 10%. Credits are placed into the buffer in years of positive sequestration, and drawn upon in years of negative sequestration; credits taken from the buffer need not be replaced on a 1-for-1 basis. Should negative sequestration exceed the amount held in the buffer, we assume that additional credits are "bought back" from the market. To be conservative, we do not adjust the amount withheld over time.[19] Finally, it is unclear whether buffer or leakage deductions are required for carbon generated from wood products. Again, to be conservative, leakage and buffer deductions are subtracted from creditable carbon generated in the Wood Products pool.

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[16] The VCS methodology explored here notes that Soil and Litter pools need not be measured, but we include them as they potentially provide carbon benefits.

[17] This assumption is likely to be conservative, as FIA data indicates that the mean rotation age of planted loblolly in the Piedmont region of South Carolina is likely less than 25 years. The age class distribution derived in Table 3 indicates that over three-quarters of planted loblolly stands in the South Carolina Piedmont are younger than 25 years of age. In a similar fashion, FIA data depicting carbon stocks as a function of stand age indicates that the mean carbon stock of privately held planted loblolly in the Piedmont region of South Carolina (156.8 Mg carbon ha^{-1}) is achieved between years 15 (150.14 Mg carbon ha^{-1}) and 20 (162.86 Mg carbon ha^{-1}) (The Carbon Online Estimator, 2008).

[18] Wood products are generated under both 25- and 50-year management scenarios. Accordingly, the net greenhouse gas benefit attributable to the wood products pool is the difference between the amount of carbon in wood products generated under a 50-year scenario minus the amount generated under the 25-year scenario.

[19] VCS allows for 15% of the current buffer reserve to be released back to the project developer if the same risk rating is maintained from one verification event to the next; future withholdings are reduced by 15% if total project risk rating is decreased. No reductions are made if risk rating increases.

6. *Harnessing Farms and Forests*[20]

Eligible pools under the Harnessing Farms and Forests accounting methodology considered here are listed in Table 2. The Calhoun pools "A horizon," "Upper B," and "B/C" are used to estimate soil carbon sequestration under this methodology. Although wood products are discussed as a potential pool in *Harnessing Farms and Forests*, no wood product accounting methodology is outlined. As a result, carbon storage in wood products is not calculated here. A **cohort group performance standard** is used to simultaneously determine baseline and additionality. No deduction is made for uncertainty. No reserve or buffer is required to be set aside, but we assume that credits are "bought back" from the market in years of negative sequestration. A leakage rate of 43% is calculated based on an equation derived from Murray et al. 2004:

$$\textbf{\textit{Leakage}} = \frac{100 * e * C_N}{[e - E * (1 + \Phi)]\, C_R}$$

Price elasticities of supply (e) and demand (E) for pulpwood are assumed to be 0.3 (an approximation of stumpage price elasticities of private timber supply in South-central and Southeastern regions as reported in Adams and Haynes 1996) and −0.4 (Willey and Chameides 2007), respectively. It is also assumed that the project comprised only a small portion of the timber market, so market share (Φ) drops from the equation. Carbon intensities are assumed to be equal both on-site (C_R) and off-site (C_N), and are likewise dropped.

7. *Draft Recommendation, Active Forest Management (RGGI)*[21]

Required and optional pools under the Draft recommendation for Active Forest Management under RGGI are listed in Table 2. So as not to overestimate the carbon sequestration in downed dead wood, the Calhoun pool "Coarse Woody Debris" is used instead of the Dead Tree pool described in Table 1. Projects are required to meet regulatory additionality criteria (Regional Greenhouse Gas Initiative 2007), baseline is determined through a modified **base-year** approach, and the rate of creditable carbon accrual is based on the project's relation to regional FIA mean[22] carbon storage. Assuming that the modeled 25-year rotation can be used to approximate pre-project conditions, we determine total project starting carbon stocks to be 6,020 metric tons carbon for both required and all pool scenarios. These values are achieved the year prior to project initiation. The inventory estimate for required pools is higher than the FIA mean for Live Tree, Standing Dead Tree and Belowground carbon stocks in the area

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[20] HFF provides technical guidance on the design and implementation of offset projects, but does not establish an explicit protocol by which offsets may be generated, reported, or registered. The protocol reviewed here is a purely hypothetical one, based on recommended concepts and provisions as outlined in HFF.

[21] Again, the protocol examined here was issued by the State of Maine in June 2008, and represents one potential method by which to include active forest management under RGGI. It has not been accepted or otherwise endorsed by RGGI.

[22] "FIA Mean" refers to the mean per-hectare carbon storage for a given forest class as reported in The Carbon Online Estimator, 2008.

(5,166 metric tons carbon[23]), while the estimate for all eligible pools is below the reported FIA mean (6,268 metric tons carbon for aboveground Live Tree, Belowground, Dead Tree, and Coarse Woody Debris). Carbon stored in wood products is determined through a **regional threshold** approach.

The draft RGGI protocol does not require a calculation of leakage, but does require 1) that the forest on which the project exists be certified, or 2) that harvesting rates not be exceptionally lower than the average removal rates for forests in that area.[24] The second of these two tests is performed here. As described in "Wood Product Methodologies" below, estimates of timber production from the project (29,269 cu ft/yr) exceed average removals for loblolly in South Carolina (26,385 cu ft/yr), so no further steps are taken to address leakage.

The current draft protocol notes that no buffer or reserve will be required if insurance is secured for the project. A buffer or reserve will be required if no insurance is secured to protect against unforeseen loss. The amount of this potential buffer is not specified in text, but twenty percent of annual creditable carbon has been suggested as a potential withholding amount. To be conservative, we consider a 20% deduction/no insurance scenario in our analysis. However, the implications of a 0% deduction/insurance scenario are discussed later in the report under "Critical Analysis of Components and Assumptions." Buffer set-asides are assumed to remain a constant proportion relative to the project carbon stock. The buffer is not drawn upon in years where emissions exceed sequestration. Instead, we assume that credits are "bought back" from the market in those years. The draft RGGI recommendation is unclear as to whether a set-aside would be required for carbon generated from wood products. To be conservative, buffer deductions are subtracted from creditable carbon generated in the Wood Products pool.

Baseline Methodologies

- Base-year (1605(b), GFC, CCX, RGGI): Baseline under a base-year approach equals the total carbon found in the ten 10-hectare plots at project inception. Under 1605(b), GFC, and CCX, all carbon accruing above the baseline is assumed to be additional. The rate of carbon accumulation under the draft RGGI protocol is based on the relation of a project's starting carbon stock to FIA mean (Figure 1). If the starting carbon stock is higher than the FIA mean, credit is awarded for 75% of the difference between the FIA mean and the starting carbon stock. All carbon above the baseline is credited at a rate of 100%. If the starting carbon stock is below the reported FIA mean for the area, credit is given for 50% of carbon accumulation above the starting carbon stock up to the point where amount of stored carbon surpasses the FIA mean. Once above the FIA mean, 100% of accumulated carbon is credited.

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[23] Because the value for Live Tree reported in Ibid. includes boles, crowns, and coarse roots, it is necessary to multiply by 0.85 to generate an estimate of the aboveground component.

[24] If harvesting rates are significantly reduced, specific project leakage must be calculated. Leakage discount rates have yet to be developed under RGGI, so this option is currently unavailable.

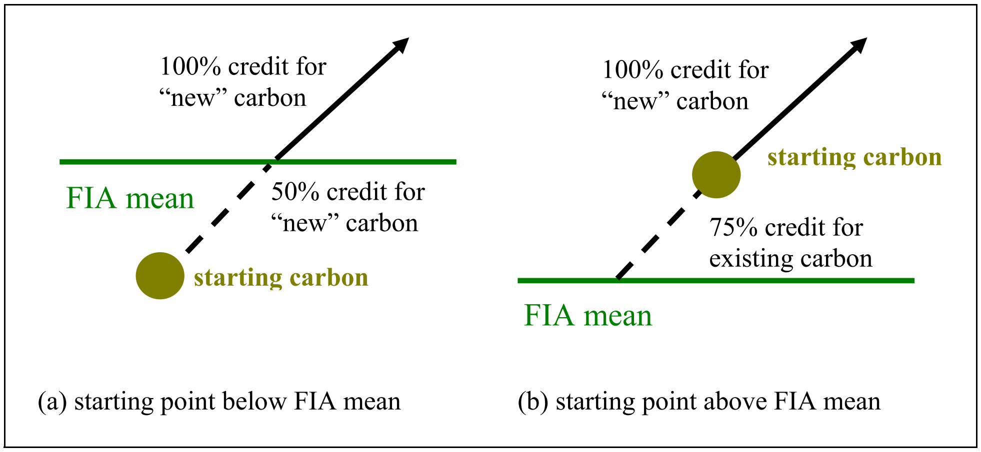

Figure 1. Rates of carbon sequestration crediting under the draft recommendation to RGGI, showing both (a) below FIA mean and (b) above FIA mean starting scenarios (Adapted from Maine Forest Service et al. 2008).

- <u>Performance Standard: Single-Practice (CCAR, VCS):</u> Baseline under a single-practice performance standard equals the estimated carbon sequestered under the management scenario that best approximates what would have been done in the absence of the project. Here, this is assumed to be a 25-year rotation scenario,[25] meaning that all stands are harvested when they reach 25 years of age. We assume that harvests would have occurred and that wood products would have been generated under the business-as-usual (BAU) scenario, so the Wood Products pool is also included in the baseline when listed as a required or optional pool under a given protocol.

- <u>Performance Standard: Cohort Group (HFF):</u> Under the cohort group performance standard considered here, both baseline and additionality are considered simultaneously using a methodology that takes into account the observed stand ages in the region. A conceptually similar method is described in Murray and Brown 2007, but here we use a stand age class distribution rather than harvest probability to generate a baseline. First, an age class distribution for all privately held planted loblolly forests in the South Carolina Piedmont sampling unit (SC-3) is derived using FIA year-2006 data downloaded via FIA DataMart (U.S. Forest Service 2008). The average carbon storage for each age class is generated by a Carbon On-Line Estimator (COLE) 1605(b) query for planted loblolly forests in the area (The Carbon Online Estimator 2008), and then multiplied by the percentage of total stands in that age class. The proportional carbon for each age class is then summed across all age classes, and used as a baseline throughout the project (Table 3).[26] No creditable carbon is earned while a project's stocking level is below the performance standard, while all carbon above the standard is eligible for crediting.

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[25] As noted above, FIA data for the region appears to bear out this assumption.

[26] It is assumed that the proportion of stands in each age class remain the same over time. In reality, the age class distributions could be updated over time to account for any shifts in regional landowner behavior.

Table 3. Stand age distribution and the contribution to carbon stocks for privately held planted loblolly pine in the Piedmont region of South Carolina (carbon stock at midpoint of age class derived from The Carbon Online Estimator 2008).

Age class	Percentage of total	Cumulative total	Carbon stock, age class midpoint (metric tons carbon/ha)	Contribution to total carbon stock (metric tons carbon/ha)
0–5	8.16%	8.16%	110.56	9.02
6–10	12.24%	20.41%	124.13	15.20
11–15	22.45%	42.86%	141.34	31.73
16–20	8.16%	51.02%	156.50	12.78
21–25	24.49%	75.51%	166.83	40.86
26–30	16.33%	91.84%	173.12	28.26
31–35	6.12%	97.96%	176.73	10.82
36–40	0.00%	97.96%	178.75	0.00
41–45	2.04%	100.00%	179.94	3.67
46–50	0.00%	100.00%	180.56	0.00
50+	0.00%	100.00%	NA	0.00
			Total, all age classes	**152.34**

Wood Product Methodologies

- 100-Year Method (1605(b), GFC, CCX, VCS): We have data on the amount of standing live tree carbon at the time of harvest, but do not have data on specific harvest volume or the makeup of harvest (e.g., percent softwood pulp, hardwood saw, etc.). For this reason, we use conversion factors listed in Smith et al. (2006) to derive harvested wood volume, fraction softwood/hardwood, fraction sawtimber/pulpwood, and fraction of wood products projected to remain in use and in landfills 100 years after harvest.

  A first step in this process is to use estimates of Live Tree carbon at the time of harvest to generate harvested volumes for hardwood and softwood pulpwood and sawtimber. This is a necessary step for us to calculate the amount of harvested wood that can be sold. To solve for harvested volume in units of $m^3\ ha^{-1}$ (***V***), we use the following equation, provided in *Example 4* of Smith et al.:

  $$\textbf{\textit{Live Tree C}}\ (\text{metric tons ha}^{-1}) = 0.5 * V * FS * FT * SG$$

  where ***FS*** is the fraction of the harvested stock that is either hardwood or softwood, ***FT*** is the fraction of the harvested stock that is either sawtimber or pulpwood, ***SG*** is the specific gravity of the species harvested, and 0.5 approximates the fraction of wood that is carbon. Values of ***FS***, ***FT***, and ***SG*** for Southern Loblolly-shortleaf pine forest types are taken from *Table 4* of Smith et al.

  After generating estimates of the volume of hardwood and softwood pulpwood and sawtimber for each harvest, we can calculate the amount of carbon stored in each by converting harvested volume back into metric tons carbon. Here we assume that all quantities of harvested wood represent industrial roundwood, and covert to metric tons carbon using conversion factors provided in *Table 4* of Smith et al. We then multiply the amount of carbon contained in harvested hardwood and softwood pulpwood and sawtimber by the fraction that is expected to remain in use or in landfills 100 years after harvest, as indicated under *Table 6-Southeast* of Smith et al. Credit for this amount is taken in the year of harvest and added to the total amount sequestered in previous years. This latter step is done to capture the additive, persistent nature of carbon stored in the Wood Products pool over time.

- Regional Threshold (RGGI): Eligibility to claim credit for carbon stored in wood products under a regional threshold approach is dependent on the relationship between project harvests and regional removals. Here, we generate estimates of timber production under a 50-year rotation scenario, and then compare that to FIA data on average removals for loblolly in South Carolina (U.S. Forest Service 2007). To calculate annual average wood product production for the project, we use the following approach:

  $$\textbf{\textit{Project Removals}} = \frac{\boldsymbol{V} * 100}{50}$$

  where **V** represents harvested volume in units of $m^3\ ha^{-1}$ as defined above, a constant of 100 scales the harvest up to the project area (100 ha), and a constant of 50 converts single 50-year rotation harvests into annualized removals. We then convert units from m^3 into cubic feet, and compare to FIA data. In doing so, we find that harvest rates from the hypothetical project (29,269 cu ft/yr) exceed the average generated by loblolly timberlands in South Carolina of similar area (26,385 cu ft/yr). The difference between these two removal rates (2,884 cu ft/yr) is then scaled back up to removals per-hectare, per-rotation, and then into wood volume, fraction softwood/hardwood, fraction sawtimber/pulpwood, and fraction of wood products projected to remain in use and in landfills 100 years after harvest using the process outlined under the **100-year method** above. Credit for carbon sequestered in wood products is taken at year of harvest and added to the total amount sequestered in previous years. This latter step is done to capture the additive, persistent nature of carbon stored in the Wood Products pool over time.

Quantification of Net Creditable Carbon

We apply the accounting procedures outlined above in "Protocol Implementation" to generate net creditable carbon (***NCC***) for a given year *n* as follows:

$$\textbf{\textit{Net Creditable Carbon}}\ (\boldsymbol{NCC_n}) = (C_n - B_n) * (1 - L_n) * (1 - U_n) * (1 - R_n)$$

where $\boldsymbol{C_n}$ is the gross carbon storage in relevant pools in year *n*, $\boldsymbol{B_n}$ is the baseline in year *n*, and $\boldsymbol{L_n}$, $\boldsymbol{U_n}$, and $\boldsymbol{R_n}$ are the percentage deductions (if any) for leakage, uncertainty, and reserve set-asides in year *n*, respectively. We then multiply $\boldsymbol{NCC_n}$ by 3.664 to generate estimates in metric tons of CO_2 equivalents (CO_2e)—the unit on which most registries or markets operate—yielding $\boldsymbol{NCCe_n}$.[27] This term is used to calculate the total amount of GHG mitigation achieved under each protocol. To calculate total GHG mitigation, we sum annual estimates of ***NCCe*** across all 100 years of project implementation.

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[27] We use an atomic mass of 44.0098 for CO_2 and 12.011 for C to determine a conversion factor of 3.664. In practice, this ratio is often shortened to 44/12, yielding a conversion factor of 3.667. In this analysis, shifting between these two factors affects total project creditable carbon by only a few tenths of a metric ton per hectare, at most.

“FIELD TEST” RESULTS

Net Carbon Sequestration[28]

On-site net carbon sequestration varies by several thousand tons depending on the protocol followed (Figure 2). Perhaps the single most significant metric for evaluating the differences between the protocols explored here is the total net creditable carbon generated across the life of the project (Table 4). For comparison purposes, 1605(b) and GFC are evaluated separately from the other protocols. Both GFC and 1605(b) were established as registries to which landowners may report gains in sequestration. As noted in Table 2, neither requires deductions for leakage or uncertainty. Likewise, neither requires the establishment of a buffer or reserve. As a result, rates of creditable carbon generation will be higher in these programs relative to the other protocols. For example, both GFC and CCX address the same required pools and use a base-year baseline approach, but GFC results in approximately 56% greater creditable carbon than CCX.

Table 4. Total cumulative, creditable carbon, and equivalent offset allowances under each protocol over 100-year project lifespan. “Required” refers to a scenario where only mandatory pools are considered, while “all” includes all eligible pools allowed under a given methodology.

Registries	Cumulative Carbon (metric tons C)	Cumulative Allowances metric tons CO_2e	metric tons CO_2e ha^{-1}
1605(b) -required	16,321	59,798	598.0
-all	16,321	59,798	598.0
GFC -required	4,903	17,964	179.6
-all	10,817	39,633	396.3
Full Protocols			
CCX -required	3,138	11,497	115.0
-all	7,641	27,995	279.9
HFF -required	3,615	13,247	132.5
-all	3,615	13,247	132.5
CCAR -required	4,678	17,138	171.4
-all	4,678	17,138	171.4
VCS -required	1,926	7,057	70.6
-all	2,139	7,837	78.4
RGGI -required	3,059	11,207	112.1
-all	4,734	17,346	173.5

Total creditable carbon differs across the seven protocols considered here, spanning nearly an order of magnitude. Among the two registries, 1605(b) allows the most creditable carbon: 59,798 metric tons CO_2e or 598 metric tons CO_2e ha^{-1} in both required and all pool scenarios. Under GFC, 17,964 metric tons CO_2e (179.6 metric tons CO_2e ha^{-1}) is generated under a mandatory pool scenario and 39,633 metric tons CO_2e (396.3 metric tons CO_2e ha^{-1}) when all pools are included. Among the full protocols, total creditable carbon in required pools after 100 years ranges from a low of 70.6 metric tons CO_2e ha^{-1} for VCS required pools to 279.9 metric tons CO_2e ha^{-1} for all CCX pools. Despite inclusion of a number of additional pools, the small change in the VCS all pool scenario as compared to the required pool scenario stems from the larger relative production of wood products in the BAU scenario. This underscores the importance that wood products accounting may play in forest management offset projects.

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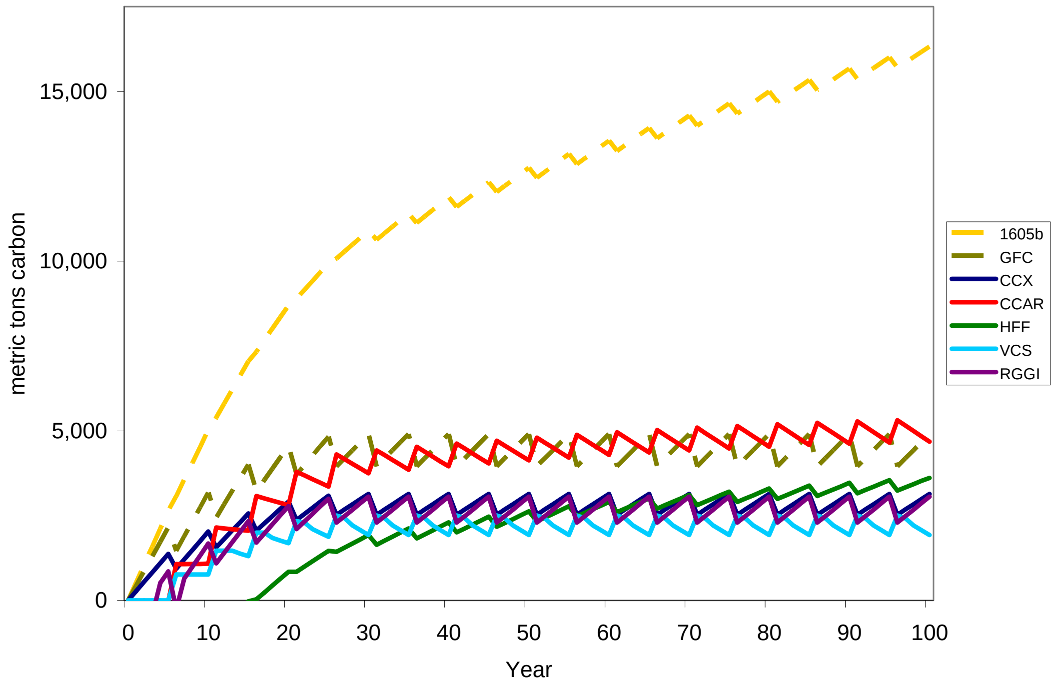
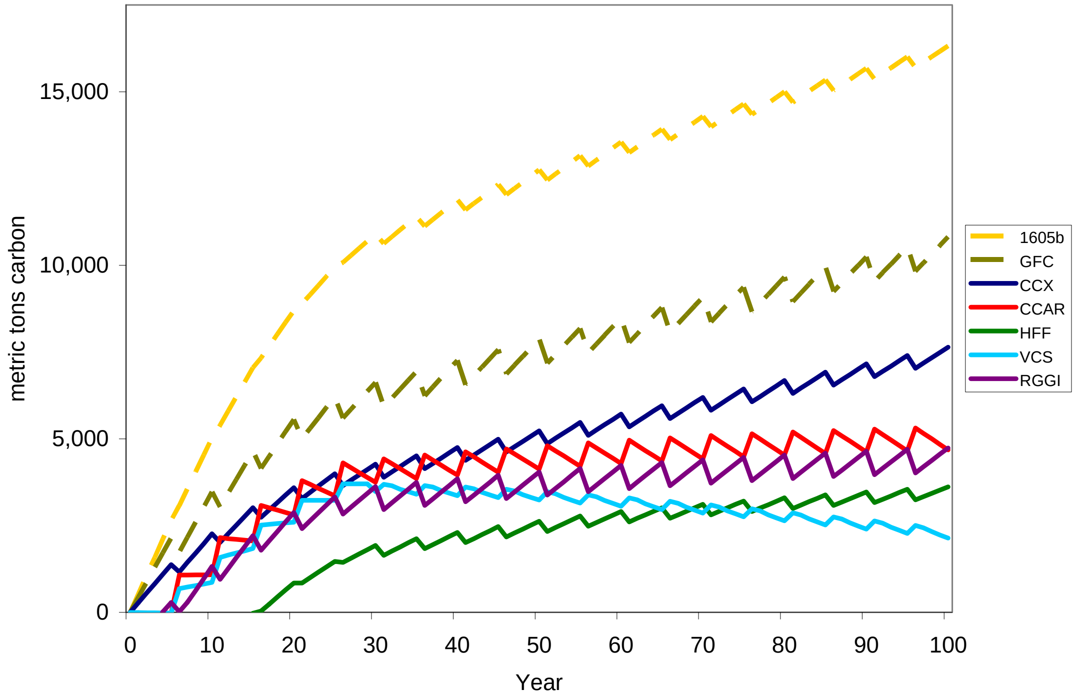
[28] This section includes revised estimates of cumulative carbon sequestration. The corrected numbers supersede earlier reported estimates.



(a) Required Pools



(b) All Pools

Figure 2. Cumulative creditable carbon generated by the hypothetical project over time, for both (a) required pools and (b) all eligible pools. Dashed lines denote registries and solid lines show full protocols.

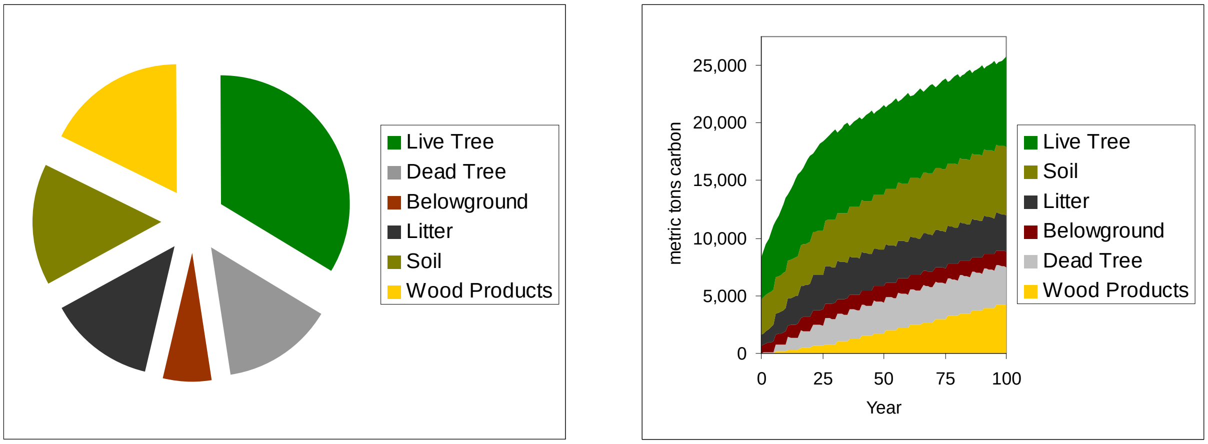
Pearson et al. (2008) briefly evaluate 1605(b), CCAR, and CCX forest management protocols, likewise finding variation in the carbon accumulated under each protocol. Notably, they find that the highest (1605(b)) and lowest (CCX) differ by a factor of 2.8. Converting our findings into relative terms, we find that 1605(b) pools generate 2.1 times the carbon allowed under CCX-all pools and 3.5 times that allowed under CCAR. Such relative comparisons are interesting, but it is difficult to make further conclusions based on a comparison of the two studies. This is because the analyses take place in different systems: Pearson et al. in Northern California and the present analysis in the South Carolina Piedmont. Different systems accumulate carbon in different pools at different rates. Protocols have themselves changed over time, and the CCX and CCAR protocols evaluated by Pearson et al. differ from those evaluated here.

Influence of Components

We find that the differences in creditable carbon generation can be attributed to a wide variety of factors (Figure 4). In some approaches, such as VCS and RGGI, creditable carbon accumulation is limited by the carbon pools included. In HFF, it is not the included forest pools, but rather an aggressive baseline and large deductions for leakage that are the primary drivers.

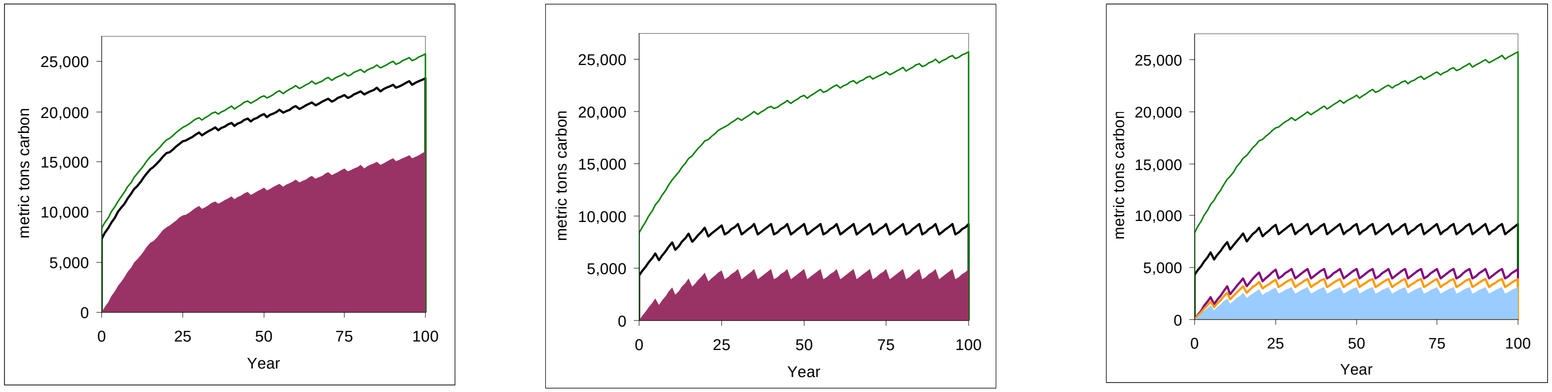
Influence of Carbon Pools

Individual carbon pools make different contributions to total on-site carbon sequestration throughout the course of the hypothetical project (Figure 3). Live Tree and Wood Products pools are heavily influenced by harvest activities. Litter and Dead Tree pools are likewise influenced by harvest activity, but to a lesser extent. These two pools are also somewhat counter-cyclical to the Live Tree pool, in that they increase immediately after harvest. The Soil pool (shown in Figure 3 as encompassing A, Upper B, and B/C Horizons) remains relatively constant, but does increase slightly over time.

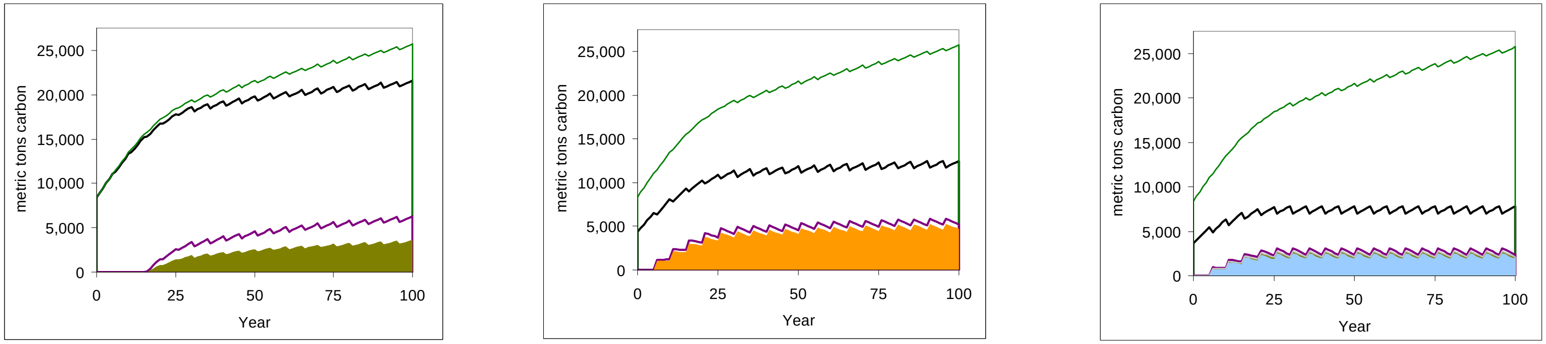


(a) (b)

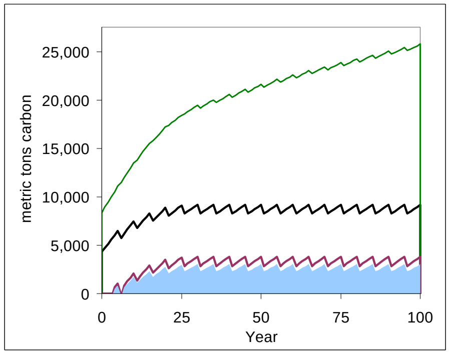
Figure 3. (a) Relative and (b) cumulative contribution of each carbon pool to total project gross carbon sequestration. Pools shown here reflect definitions as included in 1605(b).



(a) 1605(b) (b) GFC (c) CCX



(d) HFF (e) CCAR (f)VCS



(g) RGGI

Figure 4. Breakdown of creditable carbon under each methodology by accounting component, required pools only. Maximum Potential Gross Carbon is represented in **green** and is included as a benchmark; it reflects the maximum amount of carbon stored across all measured pools for a given year. Gross allowable carbon is shown in **black**, and represents the amount of carbon contained in pools required by a given protocol. All other categories reflect the carbon remaining following a specified deduction or adjustment, color-coded as follows: **baseline**; **leakage**; **buffer** or **reserve**; and **uncertainty**. Shaded portions of each figure indicate the total amount of creditable carbon remaining after all necessary deductions are made.

Box 1. Net Present Value of a Hypothetical Forest Offset Project. The ability to generate revenue through the sale of carbon credits will be a primary motivation for landowners to participate in a federal offset program. It is therefore important to consider the financial implications of the differences between the various protocols. However, because of assumptions made herein, a comparison of the relative performances between protocols is potentially more informative than absolute findings of profitability. Care must be made taken not to draw firm conclusions on the feasibility of forest management offset projects based on the rough estimates provided here.

With that in mind, it is possible to estimate net project benefits (***NB***) for a given year *n* using estimates of total net creditable carbon generated under each protocol (***NCCe***):

$$\textbf{\textit{Net Benefits}}\ (NB_n) = ((NCCe_n * P_c) + (T_n * P_t)) - ((NCCe_n * F_c) + F_m + (S_n * C_p))$$

where P_c is the carbon price, F_c is a per-metric ton carbon registration or trading fee, and F_m is a flat project registration or maintenance fee (if any). Specific fees include:

- GFC: $100 registration fee (Georgia Forestry Commission 2007)
- CCX: $0.20/metric ton total registration and trading fees (The Delta Institute 2007)
- CCAR: $500 registration and annual maintenance fee, $0.15/metric ton issuance fee (California Climate Action Registry 2008)
- VCS: €0.04/metric ton registration fee (Voluntary Carbon Standard 2007a), converted to U.S. Dollars using a conversion rate of 1.5473 USD/Euro (Federal Reserve Bank of New York 12:00 p.m. Foreign Exchange Rate, retrieved June 10, 2008 from http://www.ny.frb.org/markets/fxrates/noon.cfm).

The hypothetical project and the BAU, timber-only alternative generate timber revenue, so timber sale income and planting/preparation costs are included in net benefit calculations for each scenario. In the equation above, T_n is the amount of timber produced in year *n*, P_t is the timber price, S_n is the size of the stand (in hectares) being planted in year *n*, and C_p represents per-hectare planting costs. Specific timber prices and planting costs are listed below, and are assumed to be static over time:

- Softwood sawtimber: $38.63/green U.S. ton (Forest2Market 2008)
- Hardwood sawtimber: $24.18/green U.S. ton (Ibid.)
- Softwood pulpwood: $7.44/green U.S. ton (Ibid.)
- Hardwood pulpwood: $7.74/green U.S. ton (Ibid.)
- Planting Costs: $185.25/ha (M. Hartzler, Duke University, pers. comm., June 12, 2008)

Having generated a stream of annual net benefits and assuming a discount rate (r) of 0.05, we calculate a basic net present value (NPV) for a default 25-year rotation, timber-only scenario, and the 50-year rotation project scenario:

$$\textbf{\textit{Net Present Value}}\ (NB_0,\ldots,NB_{100}) = \sum_{t=0}^{100} \frac{NB_t}{(1+r)^t}$$

From here, we can determine the carbon price at which point each protocol and pool combination equals a BAU, timber-only scenario using a simple "solver" spreadsheet tool.

Using a discount rate of 5%, we see that there is a large disparity between the carbon prices necessary for projects to meet or exceed the NPV of timber-only management (Figure B1). Using a discount rate of 10% generates break-even carbon prices for 1605(b), GFC, CCX, CCAR, VCS, and RGGI that are approximately 60–85% of that estimated under a 5% discount rate. Break-even carbon price for HFF increases by approximately 38% when using a 10% discount.

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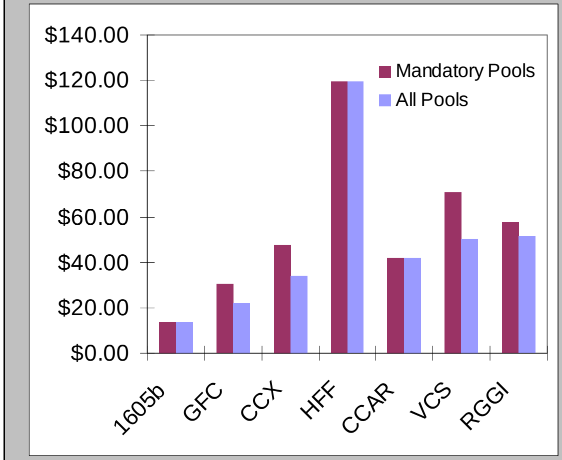

Figure B1. Carbon price ($/metric ton) necessary to match the NPV of the BAU management scenario ($r = 0.05$).

Box 1. (continued)

But again, it is important not to place too much emphasis on this example. The results are heavily influenced by the choice of management regime modeled here. Even though the transition to a 50-year rotation management regime is phased in over time, a doubling of rotation lengths represents somewhat of an extreme example. It is more likely that a land owner would extend his or her rotation length by 5 or 10 years. Under such extreme management shifts, the accumulation of carbon may come at the expense of timber harvests in the early years of the project. Future proceeds are discounted relative to those occurring in the near term, so proceeds from carbon storage will exert a stronger influence on total project NPV. This is especially important for protocols like HFF, where several years are required for the project to exceed regional carbon stocking levels.

It also is important to note that transaction costs associated with implementing a specific protocol, specifically those attributable to measuring, monitoring, and verification, are not included here. This analysis does not include any changes in transaction costs that may be attributable to conservation easement establishment, required third-party certification, or management plan creation and implementation. Likewise, it does not address the costs of carrying insurance, should insurance be required. The seven protocols examined here vary in their administrative requirements and in sampling procedures and statistical precision allowed. This is likely to lead to a variation in the costs of project implementation, and can have impacts on the profitability of an offset project.

We also assume that carbon generated under each protocol is sold at an identical, constant carbon price. However, carbon prices may change over time, and differences in the protocols and associated markets or registries may result in higher or lower prices being paid for carbon generated under a specific approach. Project developers may also need to go beyond what is required in a specific protocol to satisfy the needs of a market transaction (e.g., adjustments for uncertainty, steps to ensure permanence, etc.). Collectively, this could result in greater relative costs or income, per metric ton, of carbon being generated under one approach versus another. Further examination of the full suite of transaction costs in offset project implementation is necessary; work to better characterize these costs and their impact on offset project profitability is currently underway.

Limiting the number of eligible pools reduces the amount of carbon that may potentially be claimed, even before factoring in baseline or any relevant deductions for leakage, set-asides, or uncertainty. The Live Tree pool is capable of the greatest potential carbon sequestration, and may be easy to estimate using established inventory methodologies. However, a protocol including only Live Tree (seen in Figure 4f, for example) is fully dependent on the maintenance of on-site aboveground live biomass for the generation of creditable carbon. In this situation, simultaneously meeting timber and carbon management objectives may become more difficult. Allowing for the inclusion of additional pools may help to dampen the impact of harvest activity on project carbon storage (seen in Figure 4e, for example). This of course assumes that the gain in reported carbon storage in these additional pools outweighs the costs to measure them.

Another finding is that wood products, when included, can comprise a substantial portion of total carbon sequestration. Gains attributed to the Wood Products pool are incrementally small, but can add up over the life of the project. This is because carbon generated in the Wood Products pool represents a persistent net addition to total creditable carbon. The other pools examined here all fluctuate over time, meaning that gains in carbon sequestration one year may be offset by subsequent losses.

The extent of Wood Products pool contributions is dependent on the accounting methodology used. For example, no adjustments are made to the Wood Products pool under CCX, GFC, or 1605(b). Under the Draft Recommended RGGI protocol, gross carbon storage in the Wood Products pool is reduced by the amount of carbon storage expected in average annual removals for the area. Under VCS, wood product generation under a default 25-year rotation scenario is included within the baseline. In this latter situation, we find that more wood products are produced in the BAU scenario than in the offset project, resulting in net *negative* creditable carbon storage in the Wood Products pool over time. This is because a 50-year rotation results in more creditable carbon being generated in the Wood Products pool as compared to that generated under a 25-year, BAU rotation, but this difference is much less than the amount that would have been produced by two concurrent 25-year rotations.[29] The negative sequestration associated with wood products in this situation means that a landowner would very likely not include this pool if given the choice. If a project leads to a decrease in net harvests, however, inclusion of the Wood Products pool in the project but not the baseline can lead to substantial over-crediting.

Influence of Baseline

The baseline also has a strong influence on a project's total creditable carbon. As noted above under "Methods," the protocols examined here use three general strategies for determining project baseline: base-year (1605(b), GFC, CCX, and a modified approach under RGGI), single-practice performance standard (CCAR and VCS), and cohort group performance standard (HFF). To discern the impact of these various baseline approaches, we create a scenario in which we hold all other components (e.g., carbon pool, leakage, uncertainty, set-asides) constant. In doing so, the differential impact of the baseline approaches described above, as well as an additional approach (FIA mean carbon storage)[30] can be seen (Figure 5).

An initial and important finding seen in Figure 5 is the vastly different levels of creditable carbon yielded by the various baseline approaches. A deeper analysis of Figure 5 reveals several interesting trends and findings. A base-year approach allows the most creditable carbon to be generated. Base-year also allows for the earliest generation of creditable carbon. Under a single-practice performance standard approach, creditable carbon is generated only after project carbon stocks surpass what would have been sequestered under BAU management. The oldest stand at project inception is 20 years old, so it takes 6 years for stocks to surpass the levels of sequestration that would have been achieved under the BAU 25-year rotation scenario (assuming that stand age is the primary determinant of differences in carbon stock). The gradual decline in creditable carbon that begins around year 25 is attributable to the greater amount of wood products being produced in the BAU management scenario.

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[29] This is likely to be very different in situations where forest productivity is increased, thus increasing the output of wood products relative to the baseline scenario.

[30] Although this fifth approach is not used in any of the protocols examined here, it does factor into calculations made under HFF and RGGI. It is interesting to see how the simple use of FIA mean carbon storage data in itself compares to the creditable carbon generation derived from more involved calculations under RGGI and HFF.

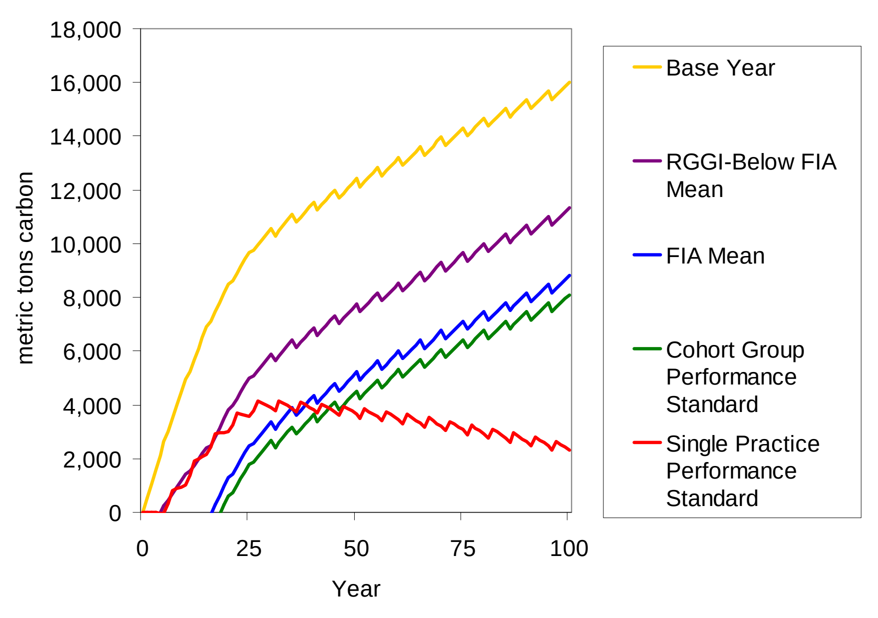

Figure 5. Creditable carbon, as influenced by baseline methodology. Carbon pools are identical under each baseline scenario, and include those described under the 1605(b) methodology (Live Tree, Dead Tree, Belowground, Litter, Soil, and Wood Products). No deductions are made for leakage, set-asides, or uncertainty.

Projects using a FIA mean and cohort group performance standard baselines do not begin to generate creditable carbon until years 17 to 19, or over 10 years later than seen under a single-practice performance standard approach. This is because FIA-based approaches capture the fact that landowners may manage their lands for rotations longer than 25 years, as well as any inherent differences in site quality that could yield greater rates of carbon sequestration across the region. The influence of regional landowner behavior can also be seen in the RGGI example. Under the draft recommendation to RGGI examined here, 50% of new carbon is credited up to the FIA mean, at which point 100% of new carbon is credited. This transition from 50% credit to 100% credit is observable in the “break” at approximately year 17.

IMPLICATIONS FOR CARBON POLICY

Critical Analysis of Components and Assumptions

Additionality and Baseline

Additionality is a general concept, and seeks to ensure that an offset project results in greenhouse gas mitigation above and beyond what would have occurred in the absence of the project. A series of project-related tests can be used to ascertain additionality. Is the project activity above and beyond what was required by law? Is the project activity profitable even absent the revenue generated by the sale of carbon credits? Independent of legal or financial considerations, is the project activity already common practice?

Baseline is closely related to additionality, and serves as a point of reference to assess the net greenhouse gas mitigation associated with an offset project. The baseline should reflect the carbon sequestration that would have been achieved in the absence of the project. Assuming that the baseline accurately reflects the amount of carbon sequestered in the absence of the project, net additional carbon storage is equal to the difference between the baseline and the total amount of carbon stored on-site and in wood products.

A central hurdle in assessing additionality and determining baseline in a forest management context is defining the course of action that would have been taken in the absence of the project. This task is complicated by the immense variety of management decisions that a forest landowner may make and the implications that these decisions have on potential carbon storage. For example, not all landowners will manage their lands to maximize timber yield. Some may choose to let their stands grow longer, and some may choose to cut them sooner or even convert to them to other, non-forest uses. Even in areas where there are specific forest management regulations or well-established and adhered-to common practices, the number of options for BAU management may be narrowed somewhat, but never whittled down to a single approach or scenario.

The protocols examined here use a variety of approaches in an attempt to overcome this hurdle. Some protocols ((1605(b), GFC, CCX, RGGI) use a base-year approach, assuming that all (or in the case of RGGI, some set percentage of) carbon sequestered above an initial inventory is additional. Others (CCAR and VCS) test for additionality at the project level, and then model carbon sequestration under a BAU default management scenario to determine baseline. Another (HFF) simultaneously determines baseline and additionality, using a cohort group performance standard that factors in regional landowner behavior and accompanying carbon storage.

The base-year approach (1605(b), GFC, CCX, and a modified approach under RGGI) allows for an easily measured and easily verified carbon stock to be used as baseline. It also removes from consideration those activities that operate outside the control of the landowner, including changes in regional land use or management. Some have argued that the base-year approach is the only way to reasonably determine baseline in forest management offset projects under most situations (Ruddell et al. 2007).

While straightforward, the base-year approach implicitly assumes that the project carbon stock would never have increased on its own, and that all accumulations are a direct result of the project. However, the base-year approach can result in the reporting and registration of significant amounts of non-additional carbon depending on the pools included and the timing of the project. Here, we find that no change in management is necessary to generate creditable carbon when using a base-year approach. Under BAU management (25-year rotations), 1605(b) generates over 500 metric tons CO_2e ha^{-1} across the 100-year life of the project. We also find that a base-year approach generates positive creditable carbon under BAU management for CCX and GFC required pools (49.4 metric tons CO_2e ha^{-1} and 77.1 metric tons CO_2e ha^{-1}, respectively). However, the influence of project timing can be seen quite easily if we delay the start of the project by 5 years (i.e., initial stand ages of 5, 10, 15, 20, 25); under this situation, BAU management results in negative total sequestration under both CCX and GFC required pool scenarios.

The baseline under RGGI is determined through a base-year type approach, and is based on a project's highest stocking levels in the past five years. The proposed RGGI methodology differs from a standard base-year approach in that the rate of carbon accumulation is based on the project's relation to the FIA mean stocking levels. The proposed RGGI approach allows for projects that begin with stocking levels below the FIA mean to be credited, but at a discounted rate. This provides incentives to increase carbon stores, and may be beneficial to those on poorer or less productive sites. The proposed approach also provides partial credit to those landowners whose initial stocking levels exceed the FIA mean. This rewards early actors and provides incentives for landowners with current high stocking levels to avoid decreasing their stocks in the future.

Unfortunately, the approach advocated under the draft recommendation to RGGI compromises the ability to fully and accurately capture the amount of additional carbon being generated by a project. The draft recommendation to RGGI currently provides little justification or basis for the discount rates applied to projects starting both above and below the FIA mean. Furthermore, providing partial credit to existing forest stands may reward early actors, but it will also provide credit to other, pre-existing conditions that had nothing to do with the carbon market. Awarding partial credit to those projects under the FIA mean can subject the system to potential gaming: landowners could simply harvest, wait five years, and then register their young (but fast-growing) stands. Here, we find that the below-FIA-mean RGGI baseline methodology results in 54.6 metric tons CO_2e ha^{-1} being generated under BAU management when applied to all pools and components described in Figure 5, but excepting Wood Products. Including the Wood Products pool would likely increase the net creditable carbon even more.

A single-practice performance standard approach (CCAR and VCS) credits only that portion of carbon sequestration that is above and beyond some BAU management scenario. By definition, no creditable carbon is generated by comparing the single-practice performance standard to the BAU management regime, as they are assumed here to be the same. A potential drawback to a single-practice performance standard baseline is that it can be subjective and difficult to verify. This is because the BAU management scenario is counterfactual: there is no way to know for sure what management regime a landowner would have implemented in the absence of the offset project. Landowners may seek to define the BAU scenario to maximize carbon storage. This susceptibility to gaming may allow for non-additional carbon to be credited.

While base-year and single-practice performance standard approaches are determined at the individual project level, a cohort group performance standard uses regional trends and data to determine baseline. Under a cohort group performance standard approach, such as the one conducted here for HFF, regional FIA data captures the fact that some landowners allow their stands to grow older, whereas others harvest sooner. The cohort group performance standard is the most conservative approach examined here. We find that no creditable carbon is generated under a cohort group performance standard approach under BAU management when applied to the pools and components as described in Figure 5, but excepting Wood Products.[31]

As in a single-practice performance standard approach, it is impossible under a cohort group performance standard to know for sure what exact management regime an individual landowner would have implemented in the absence of the offset project. This approach is also reliant on outside data to estimate the carbon stocks on comparison lands. In our project, we use FIA data to accomplish this. It may be more difficult to accurately assess regional carbon stocks for mixed stands or in areas of the country characterized by lower plot or sample intensity.

There is also the issue of how to handle those landowners that already exceed the performance standard at project initiation. This is not an issue for the hypothetical project evaluated here because initial on-site carbon sequestration was well below the baseline. It is possible that some landowners may have exceptionally high levels of carbon storage on their lands, and thus immediately generate creditable carbon with little or no change in management. If the reason behind the high carbon sequestration is due to advanced stand age, then thought must be given as to whether such a project even qualifies as "forest management"—perhaps such a situation would be better classified as "avoided deforestation" or some other project type. However, if stand age is within the range of the age class distribution used to calculate the performance standard and the high stocking levels are due to exceptional productivity, then the project should be eligible for participation.

There are also potential fairness issues associated with a cohort group performance standard approach. Landowners on particularly poor sites may have more difficulty exceeding a cohort group performance standard-set baseline than those on sites of greater quality, or may have to wait several years before any creditable carbon is generated. Landowners may also object to having their rate of carbon sequestration in some way connected to the habits of those around them.

As noted above, each strategy for assessing additionality and determining baseline has its own set of advantages and drawbacks. In evaluating these strategies, however, it is important to differentiate between public policy issues and carbon accounting issues. From the perspective of

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[31] For the purposes of this example, we consider both carbon sequestration data derived from regional age class distributions as described under "Cohort Group Performance Standard" in "Methods" and FIA mean carbon sequestration data. When applying these baseline approaches to a BAU management scenario, both approaches result in negative sequestration over the 100-year life of the project. Inclusion of the Wood Products pool in project sequestration, with no accounting for BAU wood product production, results in net positive carbon sequestration.

an emissions cap, the only criterion that matters is that the number of additional tons emitted equals the number of additional tons sequestered. Altering the accounting framework to make it easier for some landowners to participate may come at the expense of system integrity. That said, establishing a system that is robust but exceedingly onerous may discourage landowner participation and reduce the role that forests can play in a comprehensive GHG mitigation strategy.

Leakage, Buffers, and Uncertainty

This analysis finds significant variation in the treatment of leakage and other discounts. Only VCS and HFF require the quantification of leakage and provide guidelines for doing so. CCAR encourages that off-site leakage be assessed and quantified, but the process is optional at the present time. RGGI requires that harvests meet or exceed average removal rates for the area or that project lands be certified to guard against leakage. There is not yet a process for determining leakage should neither of these be the case, but leakage analyses are planned (E. Hawes, Environmental Northeast, pers. comm., September 5, 2008). Collectively, these differences in approach mean deductions ranging from 0% (CCAR and RGGI) to 10% (VCS) to 43% (HFF) of annual creditable carbon.

Requiring that projects meet or exceed average annual removals in the area, as is the case under RGGI, seems at first intuitive and may provide a quick and easy check to gauge potential leakage, especially for smaller landowners who may not have access to long-term harvest data. However, using mean values potentially penalizes those who traditionally produced less than the average. This runs somewhat counter to the motivations for RGGI’s baseline calculation strategy, whereby projects operating under the FIA mean stocking level are awarded 50% credit as an incentive to increase stocking levels. This approach also potentially shields projects that exceed average annual removals—even if a project drastically reduces its harvest activity, no accommodations are made for leakage so long as removals remain above regional averages.

The look-up table used under VCS likewise provides a quick and easy way to gauge possible leakage, but prohibits customization based on market conditions and a project’s qualities and attributes. As noted in Murray et al. (2004), leakage rates for a given activity type may vary substantially across regions, meaning that the flat discounts generated by such a simple table are likely to be either too high or too low. The most detailed method for generating project leakage comes from the methodology described under HFF. Under HFF, the relative size and carbon intensity of the project are taken into account, as well as the market for the particular products being generated. A potential drawback to this approach for calculating leakage is its dependence on accurate market data.

A potential shortcoming common to both VCS and HFF methodologies for leakage accounting is an inherent focus on individual projects. In all likelihood, activity-shifting phenomena such as leakage will require broad perspective to gauge and balance reported and actual greenhouse gas reductions (Murray et al. 2004). Although not examined here, the use of national models or assessments to estimate system-wide leakage may represent an improvement in the way leakage is addressed in a forest management offset context.

Ensuring permanence of sequestered carbon is an important issue to address if forest projects are ever to participate in a national carbon offset program. The protocols examined here address the issue of permanence in various ways, ranging from recommended or required conservation easements or long-term legal agreements (GFC, CCAR, and RGGI) to the establishment of a buffer or pool of reserve credits (e.g., CCX, VCS, and RGGI). For the purposes of this analysis, we focus solely on the creditable carbon implications of strategies to address risk and permanence.

Despite buffers being common to many protocols examined here, differences exist in the determination and administration of buffers. For example, wood products are clearly exempted from set-aside requirements under CCX. This treatment of wood products is intuitive, as the 100-year method used to determine carbon stores already accounts for projected loss and/or decay over time. Other protocols tie buffer withholding amounts to the particulars of the project, thus providing an incentive for project developers to reduce the risk of reversal. Under VCS, a project may draw down its buffer withholdings over time should its risk rating remain the same or be reduced. A similar concept is being considered under RGGI, whereby projects with less risk may be subject to little or no withholding (E. Hawes, Environmental Northeast, pers. comm., July 3, 2008). Impacts of adjusting the amount of buffer withholding can be significant: in the modeled project considered here, adjusting the RGGI withholding amounts from 20% to 0% results in an increase of approximately 2,801.7 metric tons CO_2e (required pools) to 4,336.5 metric tons CO_2e (all pools) over the life of the project.

With respect to uncertainty, there are essentially two strategies taken by the protocols examined here: minimum standards and/or graduated discounts. Graduated discounts such as those in CCX and CCAR provide an incentive for increased accuracy in data collection, but also allow the project developer to choose the best fit of discount and administrative burden. If permitted by the protocol, some landowners may opt for high discounts in exchange for the use of models or look-up tables. Others may choose to implement stringent field sampling in exchange for little or no additional discounts. In a similar sense, the letter-grading system in place under 1605(b) allows for a landowner to make trade-offs in how different components are measured, so long as a minimum score is met. Flat certainty requirements like those contemplated in HFF may guarantee high-quality data, but may effectively prohibit the inclusion of pools naturally characterized by large degrees of uncertainty.

Assumptions and Other Considerations

This analysis is dependent on a number of assumptions. A number of these assumptions are a product of the hypothetical nature of the project considered here. In actuality, much of the information assumed here would be known to the project developer.[32] Other assumptions stem from a lack of clarity in the protocols. These assumptions are best classified as "interpretations of the rules," and usually indicate a lack of clarity or completeness on the part of a particular

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[32] This includes assumptions such as the role that carbon credits play in the decision/ability to extend rotations beyond BAU (VCS: additionality); the rate of drawdown of withholding amounts over time (VCS: set-asides); data quality; and default management practices, including relevant certification, BMP usage, etc.

approach.[33] In the context of a federal offsets program, this latter type of assumption is dangerous and threatens to undermine the transparency and integrity of the system. In the course of this analysis, this type of assumption was most often encountered in the quantification of optional pools (e.g., wood products under HFF) and other optional-yet-recommended components (e.g., leakage under CCAR). To be conservative and to avoid the introduction of additional sources of error into this analysis, these calculations were simply omitted when possible.

Another important assumption in this analysis is that the sampling and modeling used to estimate carbon sequestration meets the requirements of relevant protocols. Many protocols require the use of specific methods for carbon sampling and quantification, and often place restrictions on minimum confidence intervals. Alternatively, projects may be penalized with a discount that escalates with increasing uncertainty or statistical error. As a case in point, changing assumptions over the accuracy of carbon measurement and quantification used here can result in a substantial change to the creditable carbon generated under both CCX and CCAR. Removing the 20% certainty deduction from CCX, for example, increases total project creditable carbon sequestration by approximately 2,874 metric tons CO_2e.

In some situations, assumptions about the data and its use are necessary. A key example of this are the filters applied to the FIA data used under HFF. Under HFF, the selection of comparison lands is a key step in determining project additionality and baseline.[34] HFF provides guidance on the selection of comparison lands, suggesting that such lands "resemble project lands in their physical characteristics, including weather, soil, and topography. Land management practices on comparison lands at the outset of the project should also roughly mimic those used in the region" (Willey and Chameides 2007, p47). Similarly, Murray and Brown (2007) identify region, species, management characteristics, and ownership as key characteristics to be included in the selection of "relevant parties" for the purposes of baseline calculation. The final characteristic identified by Murray and Brown, ownership, is not explicitly identified as a key characteristic in HFF. As seen in Figure 6, simply sorting by this single variable, ownership class, can result in significant differences in creditable carbon.

Additional differences may exist within the ownership classes examined here. For example, non-industrial private individuals may manage their lands very differently from large corporations. Currently, it is difficult to sort by these ownership classes because the publicly available FIA data often lumps both together as "undifferentiated private" to protect landowner privacy.

Manipulation of the area chosen for comparison can also impact baseline and subsequent creditable carbon. Including the entire state of South Carolina yields different creditable carbon estimates than those seen above. Though not indicated above, the values of creditable carbon using statewide data under both private and all ownership classes fall within the range of creditable carbon identified in Figure 6. When selecting an area for comparison, one must also

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[33] Obvious exceptions to this latter characterization are those protocols like CCX that were not designed for long-term sequestration projects, but were adapted for use in this analysis. Also excepted from this characterization are those that were not explicitly designed for implementation outside of a particular state or region (e.g., CCAR).

[34] The selection of comparison lands is also relevant to the determination of carbon accrual and crediting rates under the suggested RGGI approach.

consider the capabilities and limitations of the data being used. Examining county- or township-level data may be ideal for capturing localized management and land use trends, but may be precluded by insufficient sample size at the desired level of resolution.

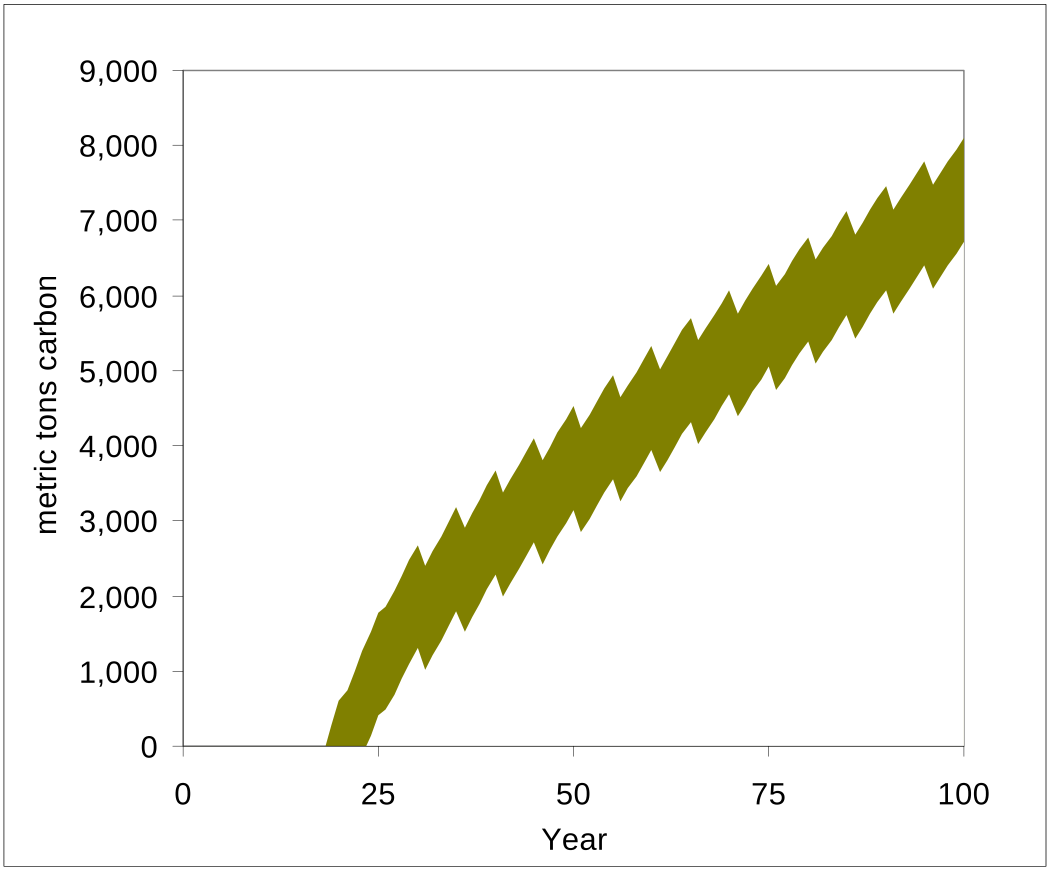

Figure 6. Range of creditable carbon, as influenced only by data used to calculate a cohort group performance standard baseline. Upper and lower boundaries are derived from 2006 FIA data on regional (SC-3) planted loblolly. The upper boundary includes only private lands, the lower all ownerships. Carbon pools are identical under each baseline scenario, and include Live Tree, Dead Tree, Belowground, Litter, Soil, and Wood Products as described under 1605(b). No deductions are made for leakage, set-asides, or uncertainty.

Assumptions made on the accounting of buffers also factor into our estimates of total creditable carbon. As noted above, buffers are not drawn from in years of negative sequestration under both CCX and RGGI, but remain a constant proportion of on-site carbon; any loss in sequestration must be bought back from the market in the same year at the given carbon price. This simplifies accounting for the purposes of this analysis, but may not fully reflect how buffers would be managed in reality. For VCS, we assume that credits in the buffer pool may be used to offset negative sequestration, but do not need to be paid back on a 1-for-1 basis in subsequent accounting periods.[35] Our treatment of the buffer in "end of the project" situations also has

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[35] Under VCS, for example, negative sequestration results in the cancellation of credits in the reserve pool. It is somewhat unclear from the text of the VCS whether canceled buffer credits must be replaced prior to issuing credits for new, additional sequestration. In referring to instances where emissions are greater than the baseline scenario, the

implications for our analysis. Under some approaches (e.g., CCX), any credits remaining in the set-aside pool are returned to the project developer at the conclusion of the project. As it is assumed here that the project is operated in perpetuity, no credits are returned to the project. The return of all remaining buffer credits in the final year of the project could represent a significant lump-sum payment.[36]

It is worth noting that our analysis does not compare the implications of using buffers versus other reversal risk mitigation strategies (e.g., insurance) in dealing with reversals. No random disturbances (fire, wind, insect infestation) are modeled here. Likewise, no insurance premium costs are included in the calculation of net project benefits for those protocols that require insurance. For these reasons, the analysis captures the "cost" of the buffer in terms of net creditable carbon, but does not fully evaluate its potential benefits or the costs of alternative strategies.

A final consideration not explored at length here, but potentially of great importance, is the role of changing conditions over time. The data on which this analysis is based comes from a site that was recently reforested. The rate that carbon accumulates on this site, versus other sites that have been forested for quite some time, is likely to be different. This is especially true in the early years of the project.

Changing rates of carbon sequestration are likewise important at the regional level. Methodologies that make use of aggregate data for baseline calculation (HFF and RGGI) can capture changing land use trends over time. A federal offsets program would likely lead more landowners to manage their lands in ways that sequester additional carbon. This would be reflected in higher mean carbon stocks and age class distributions with a greater proportion of older age classes. Under this scenario, the incremental improvement in carbon storage on the project versus on comparison lands would decrease over time. A constantly updated baseline could capture this, with the net result being a reduction in the rate of creditable carbon accumulation over the life of the project. In this situation, allowing landowners to lock in a baseline for a set period of time could provide a strong incentive for early action.

Critical Analysis of Protocols

The above analysis allows for conclusions to be drawn on the seven approaches examined here. GFC and 1605(b) are designed to provide guidance on carbon accounting and a system for registering carbon sequestration. There is no larger market associated with these two approaches, so items important to the sale of carbon credits and maintenance of market integrity—additionality, permanence, leakage—are conspicuously absent. Alternatively, CCAR, VCS,

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text states that "no future [credits] are issued until the deficit is remedied. If [credits] were issued in previous verifications, an amount of buffer credits equivalent to the emissions…is automatically cancelled from the…buffer account." The text goes on to state that "minimum buffer values for the various project types have been conservatively estimated and set at a level that should be sufficient to prevent the balance of credits in the buffer account from ever becoming negative," implying that repayment of canceled credits in the buffer is not necessary (Voluntary Carbon Standard, 2007b, p11).

[36] The same potentially holds true for post-project timber harvests. We assume that the forests are managed in a similar fashion in perpetuity, but it is possible that a landowner may choose to harvest the entire site at the conclusion of the project if so allowed by the terms of the protocol.

RGGI, CCX, and HFF have been developed for the express purpose of marketing stored carbon. Permanence, leakage, and additionality are often addressed in greater detail in each of these latter approaches. Conclusions specific to particular registries (1605(b) and GFC) and full protocols (CCX, CCAR, VCS, HFF, and RGGI) are discussed below:

Registries

- *U.S. DOE 1605(b)*

  The large number of pools included under 1605(b), combined with the base-year approach for baseline, results in a large amount of creditable carbon being generated. Most importantly, this analysis shows that the base-year approach used for baseline under 1605(b) can credit non-additional carbon. Further, 1605(b) fails to address several components necessary to market integrity. The 1605(b) technical guidelines do, however, contain extensive information and guidance on carbon accounting. This information and guidance is referenced by many of the other protocols examined here.

- *Georgia Forestry Commission Carbon Sequestration Registry Project Protocol*

  As with 1605(b), the GFC protocol base-year baseline approach may lead to non-additional carbon being credited. GFC allows for project status to be upgraded from "unrestricted" to "restricted" if conservation easements are secured for the project, but it is unclear from the text of the protocol what the implications of this are for creditable carbon. Leakage and uncertainty are not addressed.

Full Protocols

- *CCX Sustainably Managed Forests/Long-Lived Wood Products Protocols*

  The base-year approach use under CCX potentially allows for non-additional creditable carbon to be credited. A 20% buffer requirement provides some protection against catastrophic reversal. The exemption of the Wood Products pool from withholding requirements is intuitive, as loss of stored carbon over time is already factored into the amount of wood product carbon that can be credited. However, carbon sequestration attributable to BAU wood product production is not addressed. External leakage is also not addressed. The sliding scale for uncertainty deductions allows a landowner to choose the best fit of discount and administrative burden.

- *CCAR Forest Project Protocol*

  Current CCAR restrictions against the crediting of carbon in optional pools may discourage landowners from measuring and reporting these pools. Also, the single-practice performance standard approach for determining baseline requires a great deal of assumptions of how the land would have been managed in the absence of the project. Linking the BAU scenario to minimum forest practice requirements may reward some landowners for carbon that would have been sequestered anyway. Determination of external leakage is encouraged, but no method is outlined to do so. Easements and natural forest management are required to reduce the risk of loss, but no buffer or alternative risk mitigation strategy (e.g., insurance) appear to be required. As with CCX, the sliding scale used to determine deductions for uncertainty are intuitive and provides a degree of flexibility to the landowner.

- *VCS Improved Forest Management Protocol*

Like CCAR, the single-practice performance standard baseline approach under VCS has the potential to provide credit for some amount of carbon that would have been generated anyway. Under VCS, however, this potential is diminished somewhat by stricter tests for project additionality. Another important finding is the strong negative influence that inclusion of the Wood Products pool has on total creditable carbon. By tracking the Wood Products pool in both the baseline and project, however, VCS accounts for the net decrease in harvests (and subsequent reduction in carbon stored in wood products) resulting from the hypothetical project considered here. The methods for determining leakage under VCS are straightforward, but are unlikely to accurately capture leakage rates for specific projects in specific regions. The characterization of project risk and the associated buffer set-aside requirement is intuitive, and provided an incentive for landowners to improve risk rating in the process.

- *Harnessing Farms and Forests*

The cohort group performance standard approach used to determine baseline and additionality under HFF takes account of regional land use trends. By assigning regional sequestration values to a regional age class distribution, however, no account is made of differences in site quality between the project area and the regional averages. This may over- or underestimate the amount of carbon that can be stored on-site. A basis in age class distribution may also make the approach explored here difficult to apply to stands under uneven-aged management. The technique does allow for changes in land use or management to be incorporated over time. For example, age class distributions could be updated to account for any shifts in regional landowner behavior. The determination of leakage takes into account market information, but is reliant on the availability of accurate data. The importance of accurate market data is underscored by the strong influence that leakage is shown to have on net creditable carbon. HFF recommends that landowners perform a risk assessment prior to project inception, but no further risk mitigation strategy is described. Minimum data requirements are suggested, but no recommendations are provided on the adjustment of creditable carbon for uncertainty.

- *RGGI Draft Recommendation, Active Forest Management*

The baseline methodology used in this draft recommendation to RGGI potentially credits non-additional carbon. The 50% credit given for new sequestration below the FIA mean and 75% given for standing timber above the FIA mean appear arbitrary and require further justification. Requiring landowners to either carry insurance or set aside a portion of carbon sequestration as a buffer provides flexibility while potentially addressing catastrophic reversal. The use of regional harvest data to determine the net contribution of wood products is at first intuitive, but may over- or under-credit individual landowners. The simple yes-no test for leakage fails to capture project specific impacts.

Potential “Best Practice” Approaches

As noted above, the emerging carbon offsets market has created a wealth of innovation with respect to carbon accounting methodology. Different approaches have been developed to address particular needs by particular individuals in particular areas. It is therefore not surprising to see the wide variation in net creditable carbon sequestration generated by the seven protocols examined here. Rather than focusing on the differences between individual protocols, it is also possible to take many of the lessons learned from the above critical analysis and use them to identify “best practice” accounting methodologies for forest management offset projects. This provides an example of how state, regional, and voluntary market innovation can be drawn upon and utilized in the creation of a singular standard.

The best practice approaches reviewed here are based solely on a carbon accounting perspective as informed by this report. They are not necessarily the most conservative, but rather represent those approaches currently in use that most fully address the various aspects of carbon accounting. Importantly, data availability and potential transaction costs are not considered in our selection of the best practices components discussed here. Each component is described below, with the origin of the concept listed in parentheses:

- Carbon pools: Live Tree, Belowground, Dead Tree, Litter, Soil (HFF), and Wood Products (VCS) – The choice of which pools to include is a primary driver of total creditable carbon generated under each protocol. The economic feasibility of measuring and monitoring each carbon pool aside, the inclusion of all possible carbon pools has the potential to yield the greatest amount of creditable carbon for a project. Accounting for the wood products that would have been produced under a BAU scenario is necessary to capture the true GHG impacts of the project.
- Baseline/Additionality: cohort group performance standard, using regional age class distribution with site-specific carbon storage data (HFF) – The cohort-group performance standard is the most conservative approach examined here, and takes into account regional landowner behavior. By applying a regional age class distribution to site-specific data, we can approximate the implications of regional management trends on our particular site. This bypasses any concern over differences in site quality between the project area and the rest of the region.
- Buffer: risk-based, and not applied to Wood Products (RGGI, VCS, CCX) – A risk-based buffer uses project specific information to determine the amount of the set-aside. This provides some protection against catastrophic reversal while providing an incentive for landowners to improve their risk rating. The exemption of the Wood Products pool from withholding requirements is intuitive, as loss or decay of stored carbon over time is already factored into the amount of wood product carbon that can be credited.
- Leakage: market-based (HFF) – A market-based approach for calculating leakage has the potential to capture project-specific market impacts. However, the use of national models to estimate system-wide leakage may represent a future improvement to the way leakage is addressed in forest management offsets.
- Uncertainty: sliding scale with minimum data requirements (CCX, CCAR) – The sliding scale for uncertainty deductions allows a landowner to choose the best fit of discount and administrative burden while still guaranteeing a minimum level of data quality.

Inclusion of the best practice approaches should not be interpreted as a recommendation or basis for a new or separate protocol. The above list recognizes those approaches currently in use that best address the various aspects of forest management offset accounting. They are selected based on the findings generated by this report, which are in turn influenced by the particulars of the hypothetical project. Different management treatments or projects taking place in different regions may yield different results. Furthermore, forest management offset accounting continues to evolve. The ideal set of forest management offset accounting techniques may involve some combination or hybridization of the individual approaches reviewed in this report.

Conclusions and Further Analysis

Apart from significant variations in the amount of creditable carbon generated under each methodology, we also find a wide variation in the scope and stringency of carbon accounting techniques. In particular, we find that base-year approaches may allow non-additional carbon to be credited under situations similar to the one modeled here. At the other end of the spectrum, a cohort group performance standard emerges as the most conservative approach, but also as the most reliant on outside data. This has broad implications for carbon policy. Methodologies that credit large amounts of non-additional carbon threaten market and environmental integrity. Overly conservative approaches may fail to encourage the broad landowner participation needed to simultaneously meet cost-containment and greenhouse gas reduction objectives. Any eventual singular standard for forest management offsets is likely to require a balancing of the above considerations. This balancing of considerations has been largely missing thus far (Gillenwater et al. 2007).

With regard to carbon pools, limiting eligible pools to Live Tree also increases the potential conflict with traditional timber management objectives. The Wood Products pool may comprise a substantial portion of gross carbon sequestration and a strong driver in net creditable carbon generation when included. Fully accounting for the wood products that would have been produced in a BAU scenario, however, causes the Wood Products pool to become a strong, net drain on total project creditable carbon.

Although discussed in many of the protocols examined here, only two require a calculation of leakage and provide guidelines on how to do so. Even between these two, estimates of leakage differ widely. Over- or under-estimation of leakage can be minimized by customizing estimates to particular projects, or even particular types of projects in particular areas, but a full accounting of leakage will likely require national-level models or assessments.

Deductions for set-asides and for uncertainty carry their own set of lessons. While not examined here in depth, tying these deductions to project design or landowner behavior can provide positive incentives while preserving flexibility. Alternatively, a flat certainty requirement may result in projects that all meet strict data quality standards, but may increase implementation burden and effectively exclude pools naturally characterized by large degrees of uncertainty.

Relating these findings to the seven protocols examined here, we find that each methodology has its own set of strengths and weaknesses. Some, such as 1605(b) and GFC, are best characterized as registries and fail to address issues such as leakage and reversal risk. Furthermore, the base-year approach used to calculate baseline under 1605(b) and GFC can lead to the crediting of non-additional carbon. That said, both 1605(b) and GFC provide extensive technical information, tools, and tables that may be leveraged to assist landowners in carbon accounting. Regardless of the form that any eventual singular offsets standard should take, tools and technical information such as these are absolutely necessary to reduce implementation costs and administrative burden.

Turning to the other five protocols evaluated here, we again find that the baseline approaches used in RGGI and CCX can result in non-additional carbon being credited. Alternatively, the cohort group performance standard used in HFF to determine baseline and additionality is the most conservative approach examined here, but fails to account for differences in site quality between the project and the regional averages. As opposed to 1605(b) and GFC, most of the other five protocols examined here also consider issues of leakage, reversal, and uncertainty. Mandatory buffer set-asides to address reversal risk are included under several protocols (CCX, VCS, RGGI), as are deductions for leakage (VCS, HFF, RGGI) and uncertainty (CCX, CCAR).

Collectively, these findings can be used to highlight potential "best practice" approaches for forest management offset projects. These best practice approaches are based solely on a carbon accounting perspective as informed by this report, and draw upon aspects of CCX, CCAR, VCS, HFF, and RGGI protocols. Their inclusion here provides an example of how lessons learned in state, regional, and voluntary markets can be drawn upon in the creation of a singular standard.

Further Analysis

Immediate next steps are to expand the current analysis to include other systems and management treatments. In the coming months, we plan to apply the accounting methodology described in this paper to different forest types nationwide. It is important to gauge the impact that different approaches have on projects operated in different forests in different areas of the country.

An expanded evaluation of transaction costs, opportunity costs, and project profitability is also necessary. Previous research suggests that differences in third-party verification and in-field measurement requirements can influence the costs of implementing offset projects (e.g., Pearson et al. 2008). Costs can also influence whether or not any optional pools are measured and subsequently reported or registered. The exclusion of one or more potential pools of carbon can in turn reduce the total number of tons claimed by project and entered into the market. From a project developer perspective, this increases reliance on high carbon prices to make an offset project profitable. From a market perspective, a reduction in the amount of carbon offered to the market can limit the ability of forest offsets to provide cost-containment. From a greenhouse gas mitigation perspective, additional carbon that has been sequestered but not reported cannot be used to offset emissions elsewhere, thus resulting in a net increase in mitigation benefits.

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