

Transaction costs and forest management carbon offset potential

WORKING PAPER

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author's note...

At the time of publication, the Climate Action Reserve (CAR) forestry protocol was in the final stages of revision. This paper reflects version 2.1 of the protocol (issued September 2007). The analysis will be updated and reposted once the new CAR forestry protocol is finalized.

Abstract

Transaction costs are one of the key challenges that private forest landowners may face in participating in emerging carbon markets. As most forestlands in the United States occur in the form of small, privately held landholdings, the supply of forest carbon offsets could be constrained by high transaction costs. Using a custom spreadsheet model, this study examines the transaction costs of different forest offset projects operating in different forest types under different accounting methodologies or protocols. Our results suggest that transaction costs can be significant for small forest management offset projects. We find that transaction costs likewise vary by protocol and tend to decrease with project size and length of rotation extension. While transaction costs can be an important driver in total project revenue, they appear to be less of a factor than the actual accounting scheme under which the project is being operated.

1. Introduction

Domestic forests represent a significant carbon sink (U.S. Environmental Protection Agency 2008). Interest in the role that forests will play in climate change mitigation has prompted research into the potential of forest carbon sequestration for nearly two decades (Richards and Stokes 2004; Stavins and Richards 2005). In particular, studies examining the costs of forest carbon sequestration have become more sophisticated over the years in deriving marginal cost curves at national or regional scales. The amount of carbon sequestration yielded by a given amount of investment, however, gives little insight into transaction costs,¹ especially at the project level. As transaction costs are one of the key challenges that private forest landowners are likely to face in participating in emerging carbon markets (Gunn et al. 2008), this shortcoming is potentially significant. Most forestlands in the United States occur in the form of small, privately held landholdings (Butler 2008), implying that the supply of forest carbon offsets could be constrained by high transaction costs.

The role that transaction costs play in offset project implementation has been the subject of a number of analyses in recent years (e.g., Antinori and Sathaye 2007; Bilek et al. 2009; Brown et al. 2004; Mooney et al. 2004). The effect that accounting procedure— or protocol-specific methodologies and approaches have on transaction costs and overall project feasibility has received considerably less attention. Research suggests that differences in offset protocols can lead to a wide variation in the carbon credits that can be claimed by a forest landowner (Galik et al. 2008; Pearson et al. 2008; Galik et al. *forthcoming*). Large differences also exist across protocols with regard to measuring, monitoring, and verification requirements. Ultimately, these requirements can influence a project's break-even carbon price, i.e., the price required for the project to achieve net positive returns. The influence of offset protocol structure on creditable carbon generation and transaction costs also implies that accounting methodology can strongly influence project feasibility and the corresponding level of engagement in carbon markets by forest landowners (Galik et al. *forthcoming*). As forest management has the potential to be a rapidly deployable and low-cost domestic greenhouse gas (GHG) mitigation strategy (U.S. Environmental Protection Agency 2005), it is vital that policymakers understand the potential cost and supply implications of forest offset standards development.

The analysis that follows expands upon earlier research on the variation of forest management carbon offset protocols (Galik et al. 2008; Galik et al. *forthcoming*) to better document the transaction cost

¹ As used here, transaction costs are broadly defined as the costs required to design, implement, and monitor an offset project, as well as the costs of measuring, verifying, and registering the greenhouse gas benefits that result.

component of forest management offset projects. This information can then be applied to studies of aggregate supply, yielding increasingly accurate predictions of forest management offset contributions to national GHG mitigation efforts. It can also provide project participants with a better understanding of the various factors that could ultimately influence project feasibility.

2. Methods

This analysis is based on an extension of the spreadsheet tool developed in Galik et al. 2008 in which a hypothetical forest management offset project is operated under multiple accounting methodologies or protocols for a period of 100 years. The tool quantifies annual gross forest carbon sequestration, then applies a baseline and adjustments for leakage, uncertainty, and other discounts pursuant to the relevant protocols. In all, five forest management offset protocols are considered here:²

- 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);
- Climate Action Reserve (CAR) Forest Project Protocol (Climate Action Reserve 2007); and
- Voluntary Carbon Standard (VCS) Improved Forest Management Protocol (Voluntary Carbon Standard 2007a; Voluntary Carbon Standard 2007b).

A full discussion of the methodology used to calculate the carbon sequestration generated under each of the above protocols can be found in Galik et al. 2008. The present version of the spreadsheet model differs from the one utilized in that report, most notably with regard to the inclusion of a transaction cost component, scalable project sizes, and multiple forest types. These expansions and modifications are further described below.

2.1. Analysis of National Forest Types³

The spreadsheet tool developed here is capable of examining protocol performance across 46 separate regional forest types, in addition to the data set from the Calhoun Experimental Forest in South Carolina originally used in Galik et al. 2008 (see Table 2 for a full list of the forest types and regions included). Gross forest carbon sequestration for the live tree, standing deadwood, down deadwood, understory, and forest floor pools⁴ in these additional forest types is determined based on yield curves for each

² Galik et al. 2008 also considered a protocol based on a draft recommendation to the Regional Greenhouse Gas Initiative (Maine Forest Service et al. 2008) and another based on *Harnessing Farms and Forests in the Low-Carbon Economy* (Willey & Chameides 2007). These protocols are not considered here due to limited implementation experience and the large number of assumptions that would have been necessary to estimate transaction costs.

³ As opposed to the Calhoun Experimental Forest data set, the values reported for these additional forest types should not be interpreted as specific to any particular site index, stand composition, topographic position, management history, or other site-specific characteristic as the underlying equations were derived from stands with widely varying site conditions and management regimes.

⁴ Galik et al. 2008 includes soil carbon in the assessment of differences between protocols. Soil is, however, excluded in the analysis of national forest types due to the potential variability from site to site, as well as the small changes expected with continuous forest management (see Foley 2009).

forest type and Forest Inventory and Analysis (FIA)-derived ecosystem-level equations (Foley 2009, as based on Smith and Heath 2002 and Smith et al. 2006). As with the original analysis based on the Calhoun data set, the project assessed here consists of a 100-year-long rotation extension project conducted across 10 stands of equal size. Default business-as-usual (BAU) rotations for each forest type are based on harvest ages as indicated in *Appendix C* of Smith et al. 2006, while project rotation lengths are selected by the user. The model then regulates the new rotation so as to evenly space harvest activity. Following rotation extension, the initial harvest in each stand occurs at the midpoint between the BAU rotation and the new project rotation, after which the full project rotation length is implemented for all subsequent rotations. Annualized carbon storage is then determined for all protocols as described in Galik et al. 2008. A constant leakage value and buffer deduction of 10% is used for VCS under all forest type scenarios, although we acknowledge that actual values are likely to be influenced by forest type or region.

2.2. Assessment of Transaction Costs

High and low values for key transaction cost parameters were derived from project-related reports and personal communication (Table 1). Because of the inherent scale-dependency of many of the costs affecting offset projects (e.g., Mooney et al. 2004), the spreadsheet model is scalable, allowing project sizes of 100, 1,000, or 10,000 hectares to be considered. Costs were applied to each protocol based on stated project establishment and ongoing project implementation requirements, described in detail below. To provide a benchmark to the relative financial performance of each offset protocol, a BAU, timber-only alternative was also considered. The calculation of multiple metrics, including the break-even carbon price required to match the Net Present Value (NPV) of a non-offset project alternative, average per-hectare transaction costs, and transaction costs expressed in units of dollars per metric ton CO₂e, is described below.

2.2.1. Application of transaction costs to specific protocols

All projects (including BAU, timber-only project alternative). Both the BAU, timber-only project and the hypothetical rotation extension offset project share common components. In both, startup costs include site preparation, conducting of inventory, preparation of a management plan, and regeneration or replanting costs. Timber inventories and management plans are assumed to be updated every 20 years. Ongoing implementation costs include site maintenance and costs associated with marking and administering harvests. The amount of timber generated at each harvest is determined according to methodology described in Galik et al. 2008 (for Calhoun Experimental Forest data) and Foley 2009 (for all other forest types). Property tax and tax on the sale of timber, while potentially significant, are not included here due to the inherent complexity and site-specificity of each. The costs and benefits of third-party certification (e.g., Forest Stewardship Council, Sustainable Forestry Initiative, American Tree Farm System) and easement establishment can also influence project costs, but are likewise excluded here for the same reasons. These latter exclusions may particularly affect CCX (certification required), CAR (easement required), and GFC (easement optional).⁵

⁵ In addition to direct costs of easement establishment and certification, there are other potential costs or barriers that are not evaluated here. For instance, perpetual easement requirements may carry prohibitively high opportunity costs. Access to capital may limit the ability of small landowners to fund initial stages of project development or implementation.

Table 1. Values of key transaction cost parameters for projects of 247, 2,470, and 24,700 acres (100, 1,000, and 10,000 hectares).

Project Size	247 ac (100 ha)		2,470 ac (1,000 ha)		24,700 ac (10,000 ha)		Reference; Notes
	Low	High	Low	High	Low	High	
Project Establishment (timber and carbon)							
Site Preparation (acre ⁻¹)	\$0.00	\$200.00	\$0.00	\$200.00	\$0.00	\$200.00	A
Inventory (acre ⁻¹)	\$5.00	\$35.00	\$5.00	\$10.00	\$3.00	\$8.00	B
Management Plan Preparation (acre ⁻¹)	\$0.00	\$30.00	\$0.00	\$15.00	\$0.00	\$3.00	B
Planting Costs (acre ⁻¹)	\$0.00	\$250.00	\$0.00	\$250.00	\$0.00	\$250.00	A (low); C (high)
Project Establishment (carbon only)							
Carbon Project Development (acre ⁻¹)	\$0.00	\$20.00	\$0.00	\$5.00	\$0.00	\$0.65	B; Includes scoping fees, planning, project documentation
Pre-project calculations, analyses (acre ⁻¹)	\$0.00	\$5.00	\$0.00	\$2.50	\$0.00	\$0.75	B; Includes analysis of risk, leakage, social impacts, regional baselines
Conversion of inventory to carbon baseline							Includes historic calculation of baselines
Lookup Tables (acre ⁻¹)	\$0.00	\$3.00	\$0.00	\$1.10	\$0.00	\$0.35	B
From sampling (acre ⁻¹)	\$0.00	\$6.50	\$0.00	\$2.00	\$0.00	\$0.45	B
Growth modeling- first year(s) storage							Includes calculation of previous vintage credits
Lookup Tables (acre ⁻¹)	\$0.00	\$1.75	\$0.00	\$0.30	\$0.00	\$0.10	B
From sampling (automated) (acre ⁻¹)	\$0.00	\$1.75	\$0.00	\$0.30	\$0.00	\$0.10	B
Calculation of LLWP Carbon (all ytd)	\$0.00	\$3.00	\$0.00	\$0.50	\$0.00	\$0.10	B; Includes retroactive crediting up to allowable cutoffs
Initial Verification Fees (acre ⁻¹)	\$8.00	\$12.00	\$1.50	\$2.60	\$0.25	\$0.40	B
Ongoing Project Implementation (timber and carbon)							
Site Maintenance (acre ⁻¹)	\$0.00	\$5.00	\$0.00	\$5.00	\$0.00	\$5.00	A
Mark/Administer Harvests (acre ⁻¹ harvested)	\$5.00	\$120.00	\$5.00	\$110.00	\$5.00	\$95.00	B
Ongoing Project Implementation (carbon only)							
Measurement/Monitoring							
Modeling, Lookup Tables (acre ⁻¹)	\$0.00	\$0.84	\$0.00	\$0.13	\$0.00	\$0.03	B
Field Sampling/Monitoring (event ⁻¹ acre ⁻¹)	\$9.60	\$26.85	\$1.33	\$3.15	\$0.13	\$0.36	D
Annual Verification Report (event ⁻¹ acre ⁻¹)	\$6.00	\$8.00	\$1.00	\$1.50	\$0.12	\$0.18	B
Growth Modeling-annual storage							
Lookup Tables (acre ⁻¹)	\$0.00	\$1.50	\$0.00	\$0.20	\$0.00	\$0.05	B
From sampling (automated) (acre ⁻¹)	\$0.00	\$1.50	\$0.00	\$0.20	\$0.00	\$0.05	B
Calculation of LLWP Carbon (acre ⁻¹)	\$0.00	\$0.75	\$0.00	\$0.50	\$0.00	\$0.15	B
Aggregation Fee (net project revenue ⁻¹)	10.00%	12.00%	10.00%	10.00%	8.00%	10.00%	B; Sometimes include verification for smaller landowners

A. South Carolina SFI Committee 2003

B. Pers. comm., M. Smith, Forecon, Inc., January 6, 2009.

C. Brown and Kadyszewski 2005.

D. Mooney et al. 2004.

All offset projects, regardless of the protocol under which they are operating, are assessed carbon project development fees, which cover consulting fees, scoping fees, and planning, project documentation, and process determination expenses. These are assumed to be a “cost of doing business.” Carbon credits are sold to market in the year that they are generated, regardless of verification interval. Some protocols (e.g., VCS) allow sale of credits only following verification events. While this assumption does not impact the total amount of carbon generated by a particular project, it could artificially inflate the NPV of the project slightly, as expected sales are shifted forward in time. Finally, it is assumed that aggregators are not required for the projects discussed here, so no aggregation fee is assessed unless otherwise noted.⁶

1605b. All costs are calculated based on the requirements necessary to achieve a “B” measurement rating. In the case of forest projects, this means that sequestration may be quantified by either models or lookup tables adapted to local conditions and management practices. Lookup tables are assumed to be used here.⁷ No estimation is made of historical long-lived wood product (LLWP) sequestration (the amount of carbon stored in products produced prior to project inception).

GFC. An approved forester is required to assemble and register carbon data; these costs are included as part of “initial verification fees” at project inception. The assistance of an approved forester is also required in years where harvests or natural disturbances occur. Here, these costs are represented by the assessment of “annual verification report” expenses in the year of harvest. Sequestration may be quantified by either models/inventory-derived direct measurement or lookup tables; lookup tables are assumed to be used here. Annual reporting of sequestration is required, the costs of which are assumed to be included in other measurement and monitoring expenses. Calculation of historical LLWP is not conducted. A one-time registration fee is required, with projects less than 500 acres paying \$100, projects between 500 and 5,000 acres paying \$250, and projects greater than 5,000 acres paying \$500.

VCS. Analysis of project risk, leakage, and social impacts are captured in the “pre-project” expenses. A double verification is required at project inception, the costs of which are assumed to be approximated through the application of both “initial verification fees” and “annual verification report” in year 1 of the project. Individual verification events occur at five-year intervals thereafter. Initial baseline and all subsequent sequestration are assumed to be quantified through site-specific sampling. A registration fee of €0.04 is assessed to all registered credits; a conversion rate of \$1.2874 per Euro is used.⁸

CCX. Certification is required for participation, the costs of which are not included here. Carbon is quantified through a model-based accounting scheme that is derived from initial inventories. Initial verification is required, as is an annual desk audit. The costs of a desk audit are assumed to be captured in annual measurement and monitoring costs. Field verifications are conducted at the outset of a particular project, at the conclusion of the project, and intermittently as recommended by the CCX Forestry Committee. A minimum of 10% of enrolled lands are subject to field verification in any given year, therefore the cost of verification is assessed to this particular project at inception and again at 10-

⁶ In actuality, an aggregator may not be necessary for a 10,000 ha project, but will likely be required for the smaller 100 ha project. The effect of aggregation on project transaction costs is explored below.

⁷ Parameterization of models to specific site conditions and management practices (if necessary) is assumed to be included as part of “carbon project documentation” expenses at project inception.

⁸ USD/Euro Conversion citing U.S. Federal Reserve Statistical Release for the week of February 9, 2009. Retrieved February 13, 2009, from <http://www.federalreserve.gov/releases/h10/>.

year intervals. Registration and trading fees of \$0.15 and \$0.05 per metric ton CO₂e, respectively, are assessed. CCX membership fees are not assessed here.

CAR.⁹ A perpetual easement is required for project participation, the costs and potential tax benefits of which are not included here. Assessment of on-site activity-shifting leakage is required at project initiation, the costs of which are assumed to be captured in “pre-project” expenses. Baseline is quantified through models based on empirically derived project data. Project sequestration is quantified through an initial inventory and subsequent direct sampling of required pools. Sequestration is reported on an annual basis, but reported sequestration is not eligible for crediting until certified by a third-party verifier. Third-party verifiers must conduct field assessments at least every 6 years and review annual monitoring reports in the interim. The costs of field verification are therefore assessed at 6-year intervals, whereas the costs of annual review are assumed to be captured in annual measurement and monitoring expenses. A one-time project registration fee of \$500 is assessed, as is an annual \$500 registry maintenance fee. Credit registration and trading fees of \$0.15 and \$0.06 per metric ton CO₂e, respectively, are also assessed.

2.2.2. Calculation of metrics

The NPV of projects operating under each protocol, as well as the NPV of the BAU, timber-only alternative, are calculated pursuant to the methodology described in Box 1 of Galik et al. 2008.¹⁰ In addition to the costs listed therein, however, the present analysis also includes the transaction costs listed in Table 1, applied to each protocol as described above. A discount rate of $r=0.05$ is used in Galik et al. (2008), but both $r=0.05$ and $r=0.06$ are considered in this analysis.¹¹ A break-even carbon price is calculated, again following the methodology outlined in Box 1 of Galik et al. 2008. Timber prices are assumed to be \$38.63/green U.S. ton for softwood sawtimber, \$24.18/green U.S. ton for hardwood saw, \$7.44/green U.S. ton for softwood pulpwood, and \$7.74/green U.S. ton for hardwood pulp (derived from Forest2Market 2008). In this manner, we assess the direct costs and benefits of offset project implementation, as well as the opportunity costs of delaying timber harvest from the default, BAU scenario. We also consider the average per-hectare transaction costs for each protocol. This is done by averaging annual transaction costs assessed to each protocol and then dividing by the total project size. Note that the per-hectare transaction cost metric does not include a time component; there is no discounting of future costs relative to present costs.

Expanding the analysis to include additional forest types, we calculate the NPV for transaction costs for all pools under each protocol, as well as the NPV of the difference between actual creditable carbon generation under each protocol and a hypothetical maximum (1605(b)). Combined, these values provide insight into the relative magnitude of costs attributable to project implementation (i.e., transaction costs) versus accounting structure (i.e., baselines, leakage deductions, and buffer set-asides). Although project size will impact the relative importance of transaction costs versus carbon accounting on total project revenue, only results from 1,000-hectare projects are presented here.

⁹ A revised forest management protocol is currently under development; a final version of the updated protocol was not available at the time of this analysis. Early drafts of the protocol suggest significant changes to the methodology, however.

¹⁰ Because the timber prices quoted here are applicable to a limited number of forest types, this particular metric is only considered for the Calhoun Experimental Forest data set and SE loblolly-shortleaf pine.

¹¹ Higher rates may be more appropriate for the types of projects considered here, while a 5% rate allows for comparison with earlier published results.

Finally, we conduct an analysis of the per-metric ton CO₂e transaction costs for 46 forest types under multiple scenarios and project sizes. We first calculate transaction costs as described above, then divide by the discounted stream of carbon sequestration generated by the project under each protocol. A discount rate of $r=0.06$ is used to determine the present value of carbon sequestration benefits. Next, point estimates of transaction costs per ton are generated for projects by region, forest type, tract size, protocol, and rotation length extension (Table 2). To assess the marginal impact of each categorical variable on total transaction costs per unit of sequestered carbon, data are pooled, and a multivariate linear regression is estimated. Regression analysis provides a tractable and accepted procedure for relating such variation in a simple functional form. The following linear specification is applied, where the natural log of transaction costs is the dependent variable:

$$\log(TC) = \alpha + \sum_{i=1}^I \beta_i REGION_i + \sum_{j=1}^J \lambda_j TYPE_j + \sum_{k=1}^K \mu_k PROTOCOL_k + \sum_{l=1}^L \sigma_l TRACT_l + \gamma ROTATION + \varepsilon$$

Indicator variables are used to reference each i^{th} region, j^{th} forest type, k^{th} protocol, and l^{th} tract size. The length of rotation extension from each forest type’s default rotation is represented by a continuous variable ranging from 1 to 25. As in previous studies of transaction costs (Antinori and Sathaye 2007), the log transformation of total transaction costs is taken for purposes of model scaling.

Table 2. Components included in the regional transaction cost analysis.

Forest Types	Regions	Protocols	Tract Sizes	Rotation Extension
Alder-Maple	Northeast (NE)	1605b	100 ha	1-25 years
Aspen-Birch	Northern Lake States (NLS)	GFC	1,000 ha	
Douglas Fir	Northern Plain States (NPS)	CCX	10,000 ha	
Elm-Ash-Cottonwood	Pacific Northwest-East (PNWE)	CAR		
Fir-Spruce-Mtn Hemlock	Pacific Northwest-West (PNWW)	VCS		
Hemlock-Sitka Spruce	Pacific Southwest (PSW)			
Loblolly-Shortleaf Pine	Rocky Mountain-North (RMN)			
Lodgepole Pine	Rocky Mountain-South (RMS)			
Longleaf-Slash Pine	South Central (SC)			
Maple-Beech-Birch	Southeast (SE)			
Mixed Conifer				
Oak-Gum-Cypress				
Oak-Hickory				
Oak-Pine				
Ponderosa Pine				
Spruce-Balsam Fir				
Spruce-Fir				
Western Oak				
White-Red-Jack Pine				

3. Results and Discussion

The break-even carbon prices estimated in Galik et al. 2008 are approximately 4%–12% lower depending on protocol than calculated here for a comparable 100-hectare project (Figure 1).¹² This is not surprising, as the present analysis includes more cost components. The impact of adding these other transaction cost components is dampened somewhat by the addition of additional costs to the BAU, non-project alternative as well (e.g., planting, site preparation, and management plan costs).

¹² Further description of the differences between protocols and their potential impacts on creditable carbon (and by extension break-even price) can be found in Galik et al. 2008.

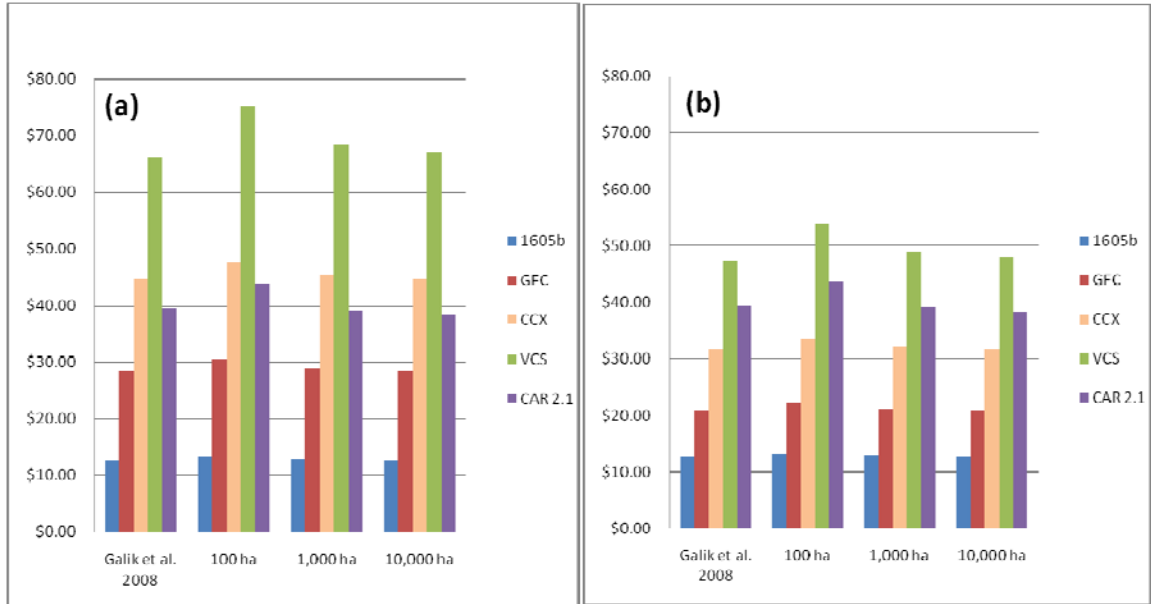


Figure 1. Break-even carbon price by protocol (\$/metric ton CO₂e) for $r=0.05$, considering (a) only required pools and (b) all pools for a doubling of rotation length for the Calhoun Experimental Forest data set (25 to 50 years). Values calculated in Galik et al. 2008 are included as a reference. Though varying by protocol, break-even prices are approximately 30% higher with $r=0.06$ for all tract sizes.

Figure 1 also shows that the break-even carbon price declines slightly as project size increases. Putting these numbers in context, we see that a project similar to the one evaluated here and operating under an accounting structure similar to 1605(b) could be viable in the early years of a domestic cap-and-trade program.¹³ Similar projects operating under accounting systems approximating CAR, CCX, or VCS may not be viable until later years of the program.^{14,15} It is important to note, however, that the management transition modeled in Figure 1, a shift from 25- to 50-year rotations, represents somewhat of an extreme example. More subtle shifts in rotations (e.g., 5- or 10-year extensions) may require significantly lower break-even prices.¹⁶

Continuing to focus solely on the Calhoun data set, the impact of project size on mean per-hectare transaction costs is easily seen (Figure 2). It is interesting to note the relative sensitivities of the different protocols to project size. Note especially the relative expenses for CCX and CAR at the 10,000-hectare project sizes. Under CCX, per-credit registration and trading fees are large drivers of the increased costs. Under CAR, costs are driven by credit and registration fees in addition to substantial project initiation and annual maintenance fees.

¹³ A recent EPA analysis of H.R. 2454, the American Clean Energy and Security Act of 2009, estimates allowance prices of \$13 to \$16 per metric ton CO₂e for years 2015 to 2020 (U.S. Environmental Protection Agency 2009).

¹⁴ EPA estimates year-2030 allowance prices under H.R. 2454 to be \$26 to \$31 per metric ton CO₂e, depending on scenario (Ibid.). Prices exceeding \$40 may not be reached until even later in program implementation.

¹⁵ The break-even carbon price as it relates to a federal market would obviously only be relevant for projects operating under methodologies that meet requirements for market participation.

¹⁶ Although differences in data source and pools included makes direct comparison with the Calhoun Experimental Forest data set difficult, a shift from 25- to 35-year rotations in 100 ha of high productivity, high management intensity SE loblolly-shortleaf pine yields break-even prices under a 5% discount rate that are between 9% and 28% of that estimated in Galik et al. 2008, depending on protocol. Break-even prices are higher under a 6% discount rate, but are still generally below comparable values reported in Galik et al. 2008.

As expected, average transaction costs are much lower in larger projects. This is because certain fixed costs (e.g., travel and in some cases administrative fees) remain constant, while variable costs decrease per unit area for larger projects (Mooney et al. 2004). As a result of high transaction costs and low absolute volumes of sequestered carbon, it is unlikely that small landowners will participate directly in a carbon market. If small landowners do participate, it is likely that they will need to make use of an aggregator. The services provided by an individual aggregator may vary, but could include project coordination and sale of credits to the market. Services may also include some degree of project oversight, such as project validation or verification. In exchange for these services, the landowner pays the aggregator a fee or a share of total carbon revenues. The role of aggregation in driving small project transaction costs depends largely on the fee charged by the aggregator and the services provided. In the example provided in Figure 3, an aggregator performs all required verification activities in exchange for a share of total project revenue. In this one example, we see that mean per-hectare transaction costs increase for all protocols under aggregation. Relative cost increases are largest in those protocols without stringent verification requirements. In these protocols, the aggregation fee simply becomes an additional cost of doing business in exchange for market access. For those protocols with stringent verification requirements (e.g., VCS), the relative increase is much smaller as the aggregator fee includes components that would otherwise be required.

While transaction costs can be an important driver in total project revenue and a potential determinant in marginally feasible projects, they appear to be less of a factor than the actual accounting scheme under which the project is being operated. In consideration of multiple forest types and rotation scenarios, we see that the relative impact of transaction costs versus carbon accounting structure is generally small, but that it does vary by protocol (Figure 4). This implies that, for many protocols and cost and pool scenarios,

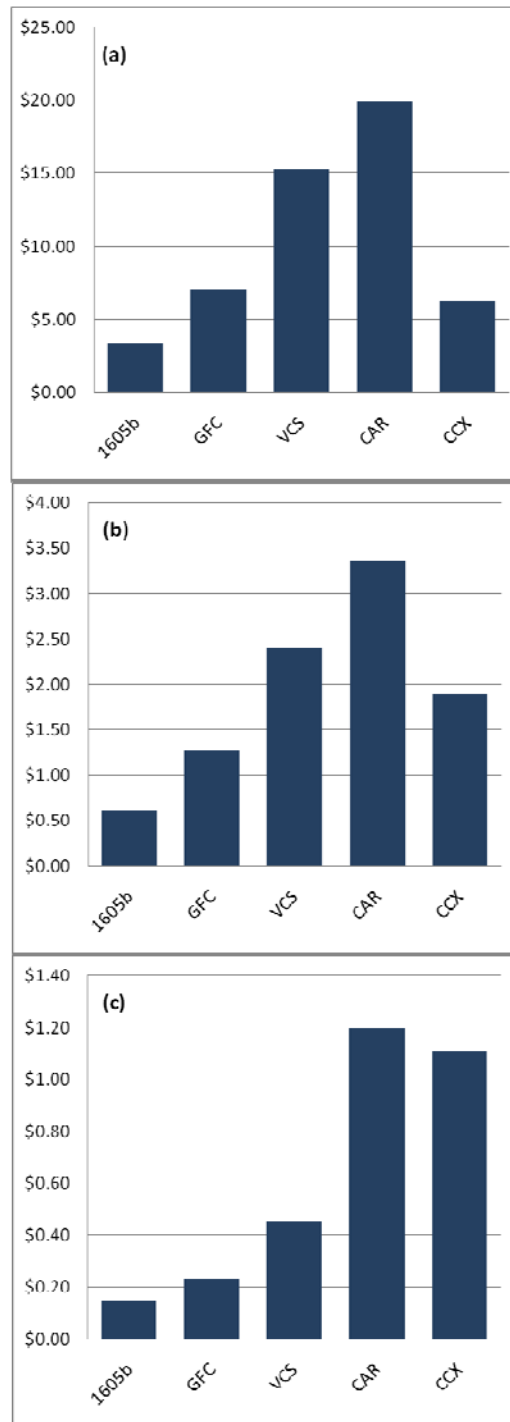


Figure 2. Mean per-hectare transaction costs (\$/ha). Represented are (a) 100-hectare; (b) 1,000-hectare; and (c) 10,000-hectare project sizes, each a 25- to 50-year rotation extension at the Calhoun Experimental Forest including all carbon pools.

limitations placed on credible carbon generation (including stringent baselines, leakage deductions, and buffer set-asides) are a stronger driver in project revenue than transaction costs. An exception here is the “all pool” scenario under GFC, in which transaction costs may approach the influence of project accounting. This is primarily a function of the similarity between the GFC and 1605(b) accounting structure: with less of a difference in credible carbon, transaction costs become more heavily weighted.

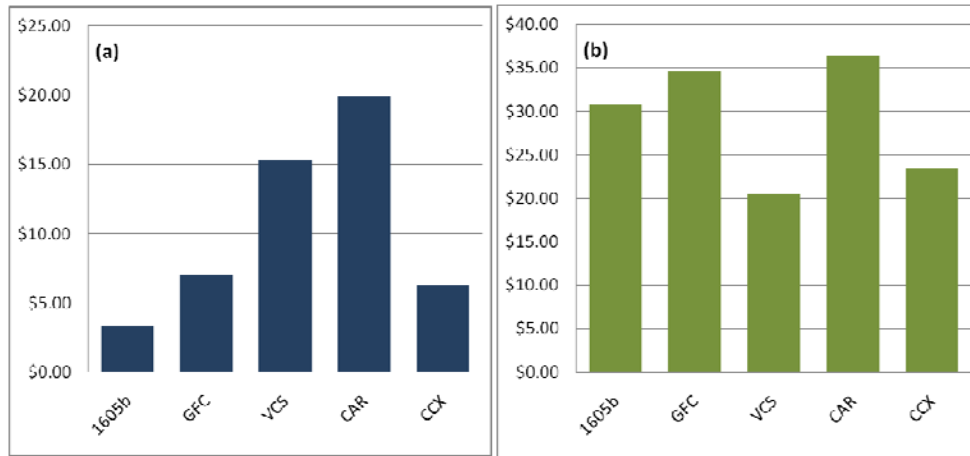


Figure 3. Impact of aggregation on small projects. Indicated are the mean per-hectare transaction costs (\$/ha) for a 100-hectare project operating at the Calhoun site (all pools), (a) without an aggregator and (b) assessed the aggregation fees described in Table 1 in lieu of verification fees.

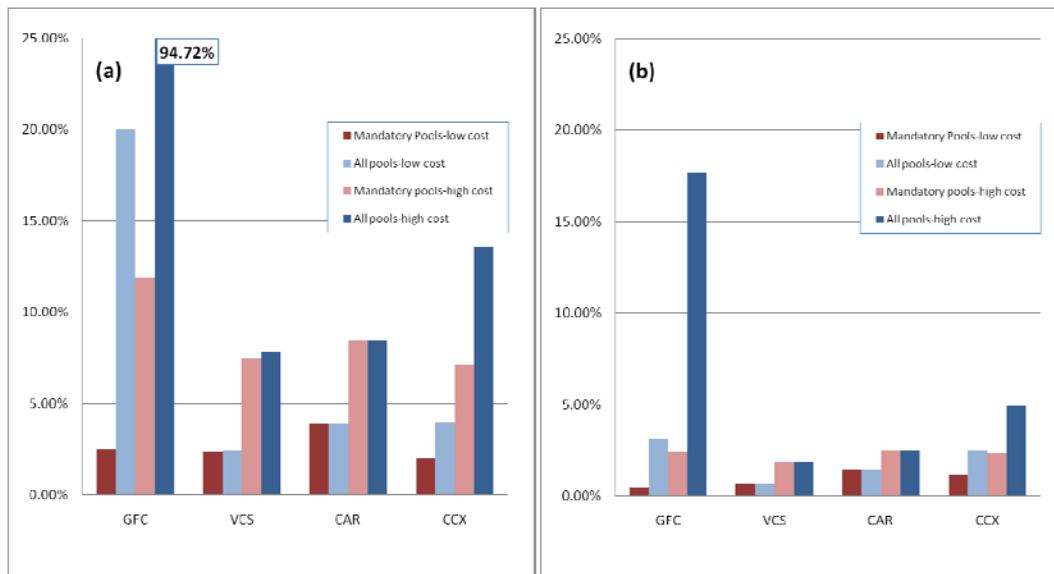


Figure 4. Ratio of transaction costs to difference in credible carbon revenue for 1,000 ha (a) Southeast Loblolly-Shortleaf Pine (45- to 55-year rotations); and (b) Western Pacific Northwest Douglas Fir (75 to 85 years) projects.

Turning to the multivariate linear regression analysis for mean transaction costs per metric ton CO₂e sequestered, we find that the model considered here is robust with high significance across estimated coefficients (Table 3). Across the full range of protocols, regions, forest types, project sizes, and rotation extension lengths considered here, mean transaction costs are estimated to be \$7.72 per metric ton CO₂e. The presence of a few high-cost outliers, mostly found in one- or two-year extensions on small tract sizes, suggests that the median value, \$1.63 per metric ton CO₂e sequestered, is perhaps a more

appropriate metric. In general, the trend is for costs to decrease with project size and length of rotation extension. Despite a great deal of variation found across forest types,¹⁷ the trend of average transaction costs falling with increasing project size¹⁸ is in general agreement with recent analysis of project transaction costs conducted at the Lawrence Berkeley National Laboratory (LBNL) (Antinori and Sathaye 2007), a study that also used regression analysis to explain the variation in transaction costs.

Table 3. Multivariate linear regression results.

Categorical Variable	Coefficient Estimate
Transaction cost	(dependent)
Constant	0.611**
Rotation	-0.040**
Tract size (1,000 ha)	-1.619**
Tract size (10,000 ha)	-3.037**
Protocol GFC	0.497**
Protocol VCS	2.445**
Protocol CCX	1.290**
Protocol CAR	2.714**
North East (NE)	0.922**
Northern Lake States (NLS)	1.024**
Northern Plain States (NPS)	1.141**
Pacific Northwest-East (PNWE)	0.732**
Pacific Southwest (PSW)	0.634**
Rocky Mountain-North (RMN)	0.651**
Rocky Mountain-South (RMS)	1.042**
South Central (SC)	0.850**
South East (SE)	0.902**
Aspen-Birch	-0.110**
Maple-Beech-Birch	-0.238**
Oak-Hickory	-0.329**
Oak-Pine	-0.303**
White-Red-Jack Pine	-0.315**
Elm-Ash-Cottonwood	-0.136**
Spruce-Balsam Fir	-0.115**
Douglas Fir	-0.358**
Fir-Spruce-Mtn Hemlock	-0.114**
Lodgepole Pine	0.126**
Ponderosa Pine	0.196**
Alder Maple	-0.320**
Hemlock-Sitka Spruce	-0.397**
Mixed Conifer	0.091 *
Western Oak	-0.264**
Loblolly-Shortleaf Pine	-0.320**
Oak-Gum-Cypress	-0.280**
Longleaf-Slash Pine	-0.270**

* indicates significance at the 5% level or better
 ** indicates significance at the 1% level or better
 Note: Multicollinearity is not likely to be a problem in this specification as forest types are not region-specific.

It is important to note that this analysis and the LBNL study differ in project scope and source data.¹⁹ Project size also largely differs between the two studies. Using undiscounted sequestration as an indication of project size, we find that the present analysis includes much greater representation of smaller projects; only at 1,000 hectares and larger do the project sizes evaluated here begin to move out of the smallest size category used in the LBNL study. Even at 10,000 hectares, the ability of projects operating under most protocols to extend into the largest LBNL category is highly dependent on rotation strategy and forest type. Further, the transaction cost data modeled here are not derived from discreet, individual projects as is the case in Antinori and Sathaye 2007. In this analysis, costs are estimated from the literature and field experience, and are applied to a much wider variety of geographical areas and project sizes. A formal model is then developed to estimate a range of transaction costs for different combinations of variables (forest type, region, etc.), and the pseudorandom data generated by the model are summarized using the regression analysis. This method allows the data to be represented in a concise, tractable manner.

Despite efforts to include as many potential drivers of forest offset project transaction costs as possible, the metrics developed here are still incomplete. It is important to note for instance that we do not include the differential cost of sampling individual pools. This means that the

¹⁷ For example, see Gutrich & Howarth 2007 for a discussion on the interplay between forest type and rotation strategy.

¹⁸ In comparing the present analysis to Antinori & Sathaye 2007, both scale (hectares) and rotation extension (years) can be used as indicators of project size as both potentially result in an increased amount of total carbon storage, the metric used in the LBNL study.

¹⁹ Ibid. include data from 11 forest offset projects operating in the U.S. and abroad, as well as a number of other project types (energy efficiency, fuel capture, renewable energy, etc.).

model does not automatically assess higher costs for protocols requiring a greater number of pools to be measured. We assume instead that this variability is captured in the range of measurement and monitoring expenses. Even so, research indicates that some pools (e.g., soil) are more expensive to sample than others (e.g., aboveground vegetation) (Mooney et al. 2004). For those protocols requiring high levels of precision, the cost of measuring optional pools can outweigh the benefit of including them (Pearson et al. 2008). Although not explored here, project length can also influence transaction costs, with the present value of transaction costs being less in longer projects than in shorter ones (Mooney et al. 2004).

The model likewise fails to fully address all factors that could influence total project sequestration. This is especially important for those metrics that consider total project revenue (e.g., Figure 1). Specifically, the model only considers even-aged management on 10 separate stands. Although shifts in rotations are phased in over time, there is currently no capability to capture the effects of pre-commercial thinning or other intermediate management. Even if the structure of the project were to match the structure of the model, other exogenous factors not included here could cause discrepancy between estimated and actual sequestration.²⁰ It is possible that these exclusions could influence the relative performance of the protocols,²¹ but the results reported here and the insight they provide are nonetheless useful due to the wide variety of forest types and accounting strategies that are considered.

Other potential sources of error are the actual transaction costs used to derive the results presented here. Values for each cost component were selected based on agreement of printed estimates in the literature and, when available, communications with professionals having direct project experience. A great deal of project-by-project variation is likely to exist, however, and the costs presented here may not be representative of the full range of project types, locations, or sizes. In particular, we note that planting and site preparation costs, as well as the fees for project development for small projects, may be higher than those quoted here.²² Measurement and monitoring fees may likewise vary significantly.

Despite these shortcomings, the results presented here, combined with the increased functionality of the underlying model, present tremendous opportunities to expand our understanding of the contribution that forest offsets can make to GHG mitigation goals. Future work involves expanding the analysis begun here to better characterize the costs of forest management offset projects. In particular, it is important to consider the full effects of rotation length, carbon prices, timber prices, aggregation, and adjustments to carbon accounting components to capture regional differences (e.g., leakage, buffer set-asides, etc.) and varying timber and carbon market conditions. It is also worth expanding the present model to include additional offset types such as afforestation/reforestation and agricultural soil sequestration.

4. Conclusion

Transaction costs can be significant for small forest management offset projects. We find that transaction costs likewise vary by protocol and tend to decrease with project size and length of rotation extension. While transaction costs can be an important component of offset project implementation, they appear to be less of a factor than the actual accounting scheme under which the project is being

²⁰ Site quality for example (see, e.g., Huang & Kronrad 2006).

²¹ For instance, management regimes that result in occasional years of negative sequestration would tend to draw out the carbon implications of protocol-specific strategies for dealing with reversals.

²² Pers. comm. G. Smith, Ecofor, April 20, 2009.

operated. As shown here, accounting adjustments (e.g., baseline, leakage, etc.) can be a stronger driver in project revenue than transaction costs. Further work is necessary to improve the sophistication of this particular model and to expand its applicability to additional project types so as to better understand the role of project accounting and transaction costs in forest offset potential.

5. References

- Antinori, C., Sathaye, J. 2007. *Assessing Transaction Costs of Project-based Greenhouse Gas Emissions Trading, Report Number LBNL-57315*. Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA. 134 p.
- Bilek, E. M., Becker, P., McAbee, T. 2009. *CVal: A Spreadsheet Tool to Evaluate the Direct Benefits and Costs of Carbon Sequestration Contracts for Managed Forests*. FPL-GTR-180. U.S. Forest Service, Forest Products Laboratory, Madison, WI. 30 p.
- Brown, S., Kadyszewski, J. 2005. *Carbon Supply from Sequestration Activities on Agriculture and Forest Lands for the SECARB Partnership*. Winrock International, Arlington, VA. 122 p.
- Brown, S., Shoch, D., Pearson, T., Delaney, M. 2004. *Methods for Measuring and Monitoring Forestry Carbon Projects in California*. 500-04-072F. Winrock International, for the California Energy Commission, PIER Energy-Related Environmental Research, 48 p.
- Butler, B. J. 2008. *Family Forest Owners of the United States, 2006*. GTR-NRS-27. U.S. Department of Agriculture, U.S. Forest Service, Northern Research Station, Newtown Square, PA. 78 p.
- Chicago Climate Exchange. 2007a. *CCX Rulebook*. 9.8.3. *Long Lived Wood Products*. Retrieved June 29, 2008, from http://www.chicagoclimatex.com/docs/offsets/CCX_Rulebook_Chapter09_OffsetsAndEarlyActionCredits.pdf
- Chicago Climate Exchange. 2007b. *CCX Rulebook*. 9.8.4. *Managed Forest Projects*. Retrieved June 29, 2008, from http://www.chicagoclimatex.com/docs/offsets/CCX_Rulebook_Chapter09_OffsetsAndEarlyActionCredits.pdf
- Climate Action Reserve. 2007. *Forest Project Protocol, Version 2.1*. Los Angeles, CA. 131 p.
- Foley, T. 2009. *Extending Forest Rotation Age for Carbon Sequestration: A Cross-Protocol Comparison of Carbon Offsets of North American Forests*. Nicholas School of the Environment, Duke University, Durham, NC. Retrieved July 20, 2009, from http://dukespace.lib.duke.edu/dspace/bitstream/10161/960/1/Foley_Final_MP.pdf.
- Forest2Market. 2008. *South Carolina Timber Report, 4th Quarter 2007. Volume 3, Number 4*. Retrieved July 1, 2008, from <http://www.state.sc.us/forest/sc07-4.pdf>
- Galik, C. S., Mobley, M. L., Richter, D. deB. *forthcoming*. A virtual “field test” of forest management carbon offset protocols: the influence of accounting. *Mitigation and Adaptation Strategies for Global Change*.
- Galik, C. S., Richter, D. deB., Mobley, M. L., Olander, L. P., Murray, B. C. 2008. *A Critical Comparison and Virtual “Field Test” of Forest Management Carbon Offset Protocols*. Climate Change Policy Partnership, Durham, NC. 45 p.
- Georgia Forestry Commission. 2007. *The Georgia Carbon Sequestration Registry - Project Protocol, Version 1.0*. Dry Branch, Georgia. 83 p.
- Gunn, J., Price, W., Battles, J., Saah, D., Siegel, K. 2008. *The Development of an Ecosystem Services Trading Program for Family Forest Landowners to Promote the Protection of Atmospheric, Water, and Soil Resources in Maine. Final Report Submitted to the USDA Natural Resources Conservation Service Conservation Innovation Grants Program*. Trust to Conserve Northeast Forestlands, New Gloucester, ME. 61 p.

- Gutrich, J., Howarth, R. B. 2007. Carbon sequestration and the optimal management of New Hampshire timber stands. *Ecological Economics* 62: 441-450.
- Huang, C.-H., Kronrad, G. D. 2006. The effect of carbon revenues on the rotation and profitability of loblolly pine plantations in East Texas. *Southern Journal of Applied Forestry* 30(1): 21-29.
- Maine Forest Service, Environment Northeast, Manomet Center for Conservation Sciences, Maine Department of Environmental Protection. 2008. *Recommendations to RGGI for including new forest offset categories: a summary*. Retrieved July 22, 2009, from http://www.maine.gov/doc/mfs/mfs/topics/carbon/docs/pdf/recommendations_to_rggi_061108.pdf
- Mooney, S., Brown, S., Shoch, D. 2004. *Measurement and Monitoring Costs: Influence of Parcel Contiguity, Carbon Variability, Project Size and Timing of Measurement Events*. Winrock International, Arlington, VA. 20 p.
- Office of Policy and International Affairs. 2007. *Technical Guidelines - Voluntary Reporting of Greenhouse Gases (1605(b)) Program*. U.S. Department of Energy, Washington, D.C. 318 p.
- Pearson, T., Brown, S., Andrasko, K. 2008. Comparison of registry methodologies for reporting carbon benefits for afforestation projects in the United States. *Environmental Science and Policy* 11(6): 490-504.
- Richards, K. R., Stokes, C. 2004. A review of forest carbon sequestration cost studies: a dozen years of research. *Climatic Change* 63: 1-48.
- Smith, J. E., Heath, L. S. 2002. *A Model of Forest Floor Carbon Mass for United States Forest Types*. RP-NE-722. U.S. Department of Agriculture, Forest Service Northeastern Research Station, Newtown Square, PA. 37 p.
- Smith, J. E., Heath, L. S., Skog, K. E., Birdsey, R. A. 2006. *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States*. GTR-NE-343. U.S. Department of Agriculture, Forest Service Northeastern Research Station, Newton Square, PA. 222 p.
- South Carolina SFI Committee. 2003. *A Landowner's Guide to Forestry in South Carolina*. Retrieved February 20, 2009, from <http://www.clemson.edu/extfor/SC%20Landowners%20Guide%202.pdf>
- Stavins, R. N., Richards, K. R. 2005. *The Cost of U.S. Forest-Based Carbon Sequestration*. The Pew Center on Global Climate Change, Washington, D.C. 52 p.
- U.S. Environmental Protection Agency. 2005. *Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture*. EPA 430-R-05-006. Office of Atmospheric Programs, Washington, D.C. 154 p.
- U.S. Environmental Protection Agency. 2008. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006*. 430-R-08-005. Washington, D.C. 473 p.
- U.S. Environmental Protection Agency. 2009. *EPA Analysis of the American Clean Energy and Security Act of 2009 HR 2454 in the 111th Congress*. Office of Atmospheric Programs, Washington, D.C. 53 p.
- Voluntary Carbon Standard. 2007a. *Voluntary Carbon Standard 2007*. Retrieved June 10, 2008, from <http://www.v-c-s.org/docs/VCS%202007.pdf>
- Voluntary Carbon Standard. 2007b. *Voluntary Carbon Standard: Guidance for agriculture, forestry and other land use projects*. Retrieved June 10, 2008, from <http://www.v-c-s.org/docs/AFOLU%20Guidance%20Document.pdf>
- Willey, Z., Chameides, B. (Eds.). 2007. *Harnessing Farms and Forests in the Low-Carbon Economy - How to Create, Measure, and Verify Greenhouse Gas Offsets*. Duke University Press, Durham, NC and London, UK.