Carbon Credit Eligibility under Area Regulation of Harvest Levels in Northern Minnesota

John S. Gunn, David S. Saah, Kathryn Fernholz, and David J. Ganz

Abstract: We evaluated the implications of area regulation of harvest on eligible carbon under both the Voluntary Carbon Standard (VCS) and the Chicago Climate Exchange (CCX) for public forest lands in north central Minnesota (89,840 ha total). We used data from the carbon submodel of the US Forest Service Forest Vegetation Simulator (Lake States variant) to evaluate changes in forest carbon stocks under different management scenarios. Baseline harvest intensity was defined by considering the manager's short-range tactical plans and the distribution of harvests by cover type and intensity class then became the "business as usual" (BAU) for use in the calculation of eligible carbon under the VCS and CCX. Under VCS, the most effective way to increase carbon stocks while meeting other management objectives was to shift harvest practices to lower intensity entries and retain higher residual basal areas. The carbon stock change rates for each manager varied significantly under the BAU scenario and resulted in a mean annual net decrease. Because CCX carbon credit eligibility requires a net increase of carbon stocking from the base year, area regulation may create periods of time where there is no eligible carbon volume. An alternate management strategy that uses the area regulation method, reduces harvest intensity, and decreases overall acreage harvested was able to provide higher postharvest carbon stocks versus the BAU scenario under VCS. FOR. SCI. 57(6):470–478.

Keywords: carbon sequestration, area regulation, carbon credits, forest management, ecological restoration

Managed Forests and Carbon Markets

IN THE UNITED STATES, the forest sector plays a critical role in addressing climate change by sequestering the equivalent of 10% of annual domestic carbon dioxide emissions (Woodbury et al. 2007). Forest management has an additional potential of 100–200 Tg yr^{-1} with appropriate development of technology and practices and technical assistance to land managers (Birdsey et al. 2006, Rice 2006). Carbon markets and regional climate change policies are developing that allow emitters of greenhouse gases (GHGs) to offset their emissions through carbon sequestration projects. The volume of voluntary carbon offset credits traded in 2008 was nearly double that of 2007 (Hamilton et al. 2009). Regulatory market volume also increased similarly, but those markets do not yet recognize carbon credits originating from managed forests. Only a small percentage (1%) of voluntary over-the-counter transactions involved forest management carbon credits in 2008 (Hamilton et al. 2009). The percentage of forest management projects is likely to increase as offset standards mature, experience is gained with existing standards, and managed forest offsets are allowed under international and US climate agreements.

A forest-based strategy to reduce atmospheric GHG is viewed as an opportunity to simultaneously reward forest conservation and responsible forest management (Fernholz et al. 2008). However, experiences throughout the United States—through the launch of state and regional GHG cap and trade schemes, voluntary GHG credit-trading and offset projects, and attempts to enlist landowners to bring carbon to market—demonstrate that storing more carbon in forests as a climate mitigation strategy faces technical and political hurdles, including uncertainty around the best practices to achieve carbon storage objectives (e.g., Luyssaert et al. 2008, Ingerson 2009, Nunery and Keeton 2010). Regardless of these factors, if the financial benefits are robust enough, carbon markets and standards could drive forest management decisions. Opportunities for landowners to sell carbon credits may compete with the need for the production of traditional forest products such as paper and lumber and biodiversity or ecological restoration objectives.

At the time of the work described here, three primary carbon offset standards were relevant to forest landowners in the United States: the Chicago Climate Exchange (CCX), Climate Action Reserve (CAR), and the Voluntary Carbon Standard (VCS). CAR had not yet developed a forest project protocol applicable outside of California, nor had VCS approved any specific Improved Forest Management methodologies. CAR has since approved a Forest Project Protocol Version 3.1 that could be applied throughout the United States (Climate Action Reserve 2010). Although VCS has also approved a methodology dealing with even-aged forest management, it is not applicable in the scenario we describe below (Voluntary Carbon Standard 2010). Each standard is unique in how it deals with critical issues such as baselines, additionality, permanence, and leakage (Ruddell et al. 2007, Beane et al. 2008). The American Carbon

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Registry (ACR) has also emerged with Improved Forest Management methodologies under development for US forests (American Carbon Registry 2010). The differences in forest offset protocols have implications for landowners whether they create incentives to accumulate short-term forest carbon stocks with limited regard for other ecological considerations (e.g., long-term species composition, age class distribution, and natural range of variability) or whether the protocols create incentives to meet multiple objectives. Protocols that include additional ecological considerations may benefit landowners seeking to balance financial objectives with restoration of biodiversity and long-term forest resilience to climate change. Forest managers need to understand the implications of carbon offset protocols to evaluate options, and policy makers require the same understanding to ensure that carbon mitigation practices do not substantially compromise other ecosystem service values provided by forests. This study addresses these needs by using readily available timber inventory data and carbon models to evaluate the carbon credit opportunities available to land managers in north central Minnesota who have long-term forest management objectives that include ecological restoration.

Area Regulation versus Volume Regulation Silviculture

Forest managers will often use area regulation rather than volume regulation to determine harvest levels when managing for biodiversity or restoration objectives. The principle of area control is to harvest and regenerate the same total area each year or per period as would be harvested in a fully regulated forest (i.e., a forest with a normal age class distribution or the same total area in each age class). The area control approach can be designed to ensure that the regulated structure is attained within one rotation, especially within an even-aged stand. The initial use of area control in a forest that is irregular in age class structure or site quality can yield fluctuating annual timber harvest volumes while regulation is being achieved. The objective of area control is to establish a fully regulated forest and an annual harvest level of approximately equal area (Alexander and Edminster 1977). The area regulation method tends to result in changes from the initial forest conditions. Alternatively, volume regulation uses the age, species, and volume structure of the initial forest to determine a stable harvest rate and volume. The objective of a volume control method is a yearly harvest of approximately equal volume, and it tends to result in the maintenance of the initial forest conditions (Davis and Johnson 1987, Leuschner 1990). Volume regulation does not ensure that a regulated forest is attained after one rotation.

Volume control provides an efficient and effective estimate of harvest level for an unmanaged forest and can assess whether such a harvest level can be maintained. These benefits have made volume control a popular way to calculate sustainable harvest levels (i.e., Annual Allowable Harvest). Traditionally, volume control has been seen to have two major disadvantages. First, growth information on unmanaged stands is often unavailable and difficult to obtain. Second, a lack of formal control on the size of annual treatment areas makes it difficult to ensure that the forest is moving toward a regulated condition and can create challenges for annual harvest planning. Volume control is intentionally designed to focus on the single objective of achieving a specific and consistent harvest volume. Rarely do landowners have objectives that can be expressed so simply.

Given the conception of the fully regulated forest, area control can be used to guide the amount of acreage entered for harvesting each year in an uneven-aged forest. Application of area control as a way of bringing an unregulated uneven-aged forest into a regulated condition may address specific landowner objectives that are not tied to harvest levels (such as carbon stock retention and other ecosystem services). Often it is not possible to achieve the desired diameter structure in a few cutting cycles; the needed residual trees may just not be there or regeneration may not be as prompt or ample as needed. Given these challenges, it is difficult to ensure a fully regulated forest over a set time period when area regulation is used in an uneven-aged forest, especially compared with even-aged systems (Davis and Johnson 1987).

Past land use history in managed forest landscapes largely determines the current condition of cover types and age classes (Rhemtulla et al. 2009 and others cited within). Areas of north central Minnesota have experienced extensive timber harvesting and periods of agricultural land uses, which have led to the creation of a mix of young and transitional stage aspen forests and transitional/mature northern hardwood forest types that probably exist outside of the historical range of natural variation (Aitkin County Land Department 2001, Brown and White 2002). Some landowners in the region have chosen to manage for a desired future condition that is more reflective of the historical range of variability (Sarr et al. 2004). Landowner objectives that include the restoration of age class distributions and cover type dominance consistent with a range of natural variability will probably involve irregular harvest activities that generate variable harvest volumes dependent on the current age class and cover type distribution, consistent with the initial use of area regulation. For example, a landowner may be interested in establishing a cover type distribution that includes a larger proportion of long-lived species, such as converting some areas of aspen (*Populus* spp.) cover types to northern red oak (*Quercus rubra*) and sugar maple (*Acer saccharum*) types that provide longer-term carbon sequestration and higher-value forest products. If the current landscape contains a high proportion of aspen in older age classes, the landowner may choose to harvest those stands at a rate that exceeds short-term growth and would exceed a volume regulation definition of Annual Allowable Harvest. Managing forests in this manner to achieve a desired future condition rather than achieve a regular flow of timber will often result in irregular harvest volumes and a concomitant irregular standing volume of carbon biomass. With increasing demands on the services that forests provide, it is likely that more landowners will choose to use an area regulation method to achieve a desired future condition that meets carbon (Keeton 2006), biodiversity (Lindenmayer and Franklin 2002), and forest health objectives (Kolb et al. 1994). Without proper evaluation through field testing and third-party certification audits, carbon standards may inadvertently drive management decisions that are counter to these multiple objectives.

Study Area and Methods

Study Area

We evaluated carbon credit eligibility using data and management plans from publicly owned tax-forfeited lands managed by the Aitkin County Land Department (ACLD) (89,840 ha) in north central Minnesota (Figure 1). The lands comprise tax-forfeited parcels located throughout the county acquired since the 1930s. Acquisition of land was frequently preceded by intensive timber harvests (to capture the remaining value from the parcel), which left the forest in a degraded condition. The result of this land use history is a patchwork of degraded and scattered parcels throughout the study area. ACLD's ownership is dominated by aspen and northern hardwoods cover types (Aitkin County Land Department 2001). The restoration objectives of the ACLD include moving the current highly modified forest to a desired future condition that is consistent with a "natural character" of cover types and age classes expected for the region (Aitkin County Land Department 2001).

Timber Inventory

The ACLD provided inventory and removal data summaries for the years 1997–2007. The stand inventory data are based on the CSA forest stand mapping and information system used by the Minnesota Department of Natural Resources to inventory the approximately 2 million ha administered by the state. The CSA inventory is a stand-level inventory that provides information on cover type, stand size, stocking, and composition, stand age, health and condition, and some measures of site productivity. ACLD provided stand-level inventory data linked to a geographic information service (GIS) spatial database.

ACLD provided summaries of forest inventory stocking levels from 1997 to 2007 to establish a historical baseline condition. In addition, harvest data were provided for the same time period to allow the evaluation of historical harvest activity levels (Table 1). Strategic (long-term) and tactical (2008–2010) management plans were provided by the county to describe management objectives (by intensity class and cover type) and to clearly define current silvicultural practices appropriate for each cover type. Quantitative silvicultural prescription data (e.g., mean starting basal area and mean residual basal area) were provided by ACLD from postharvest data collected from 1997 to 2007. These data were important for use in the modeling of harvest scenarios.

CCX Eligibility

CCX defines eligible carbon as the net accumulation of carbon stocks over time (Chicago Climate Exchange 2008). Forest growth with mortality and harvest volumes removed over time can be modeled to determine the potential eligible carbon volume. These future carbon stocks ultimately need to be evaluated in the field through inventory data, but approved growth models are commonly used at the start of a project to determine eligibility. The Lake States variant of the US Forest Service Forest Vegetation Simulator (FVS) with the associated carbon submodel of the Fire and Fuels Extension is an approved model under CCX requirements.

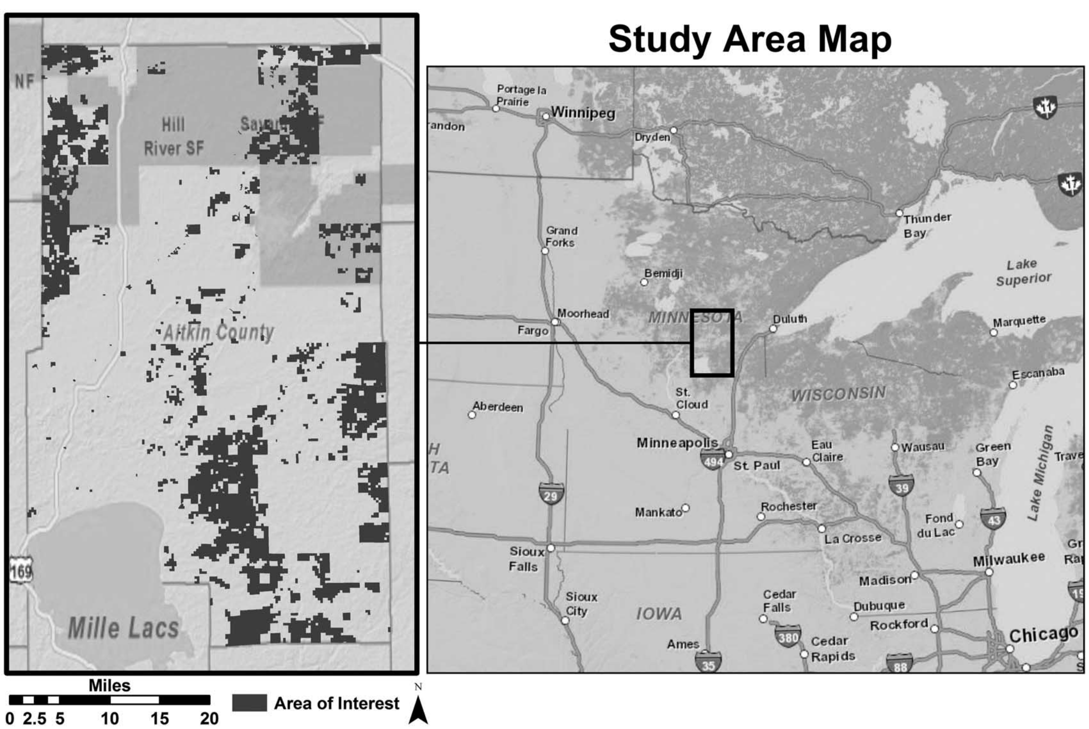

Figure 1. Study area location: lands owned and managed by Aitkin County Land Department, Minnesota, USA.

Table 1. Aitkin County Land Department (ACLD) harvest area by intensity class (high, medium, or low).

Harvest intensity	Historical harvest (1999–2007)	2008–2010 tactical plan (BAU)	Alternate management scenario	BAU area harvested	Alternate area harvested
	. . . . (% of total area harvested)	. . . .		. . . . (ha)	. . . .
High	44	49	35	809	518
Medium	18	15	12	243	170
Low	38	36	53	599	785
Total				1,651	1,473

Historical harvest area is based on management records; Business as usual (BAU) is derived from the ACLD 2008–2010 tactical management plan. The alternate management scenario was proposed by ACLD land managers.

Therefore, to determine eligible carbon through the CCX process, in this study we used the FVS model to "grow" the current inventory (staring in 2008) for 9 years while implementing a planned harvest regime based on the ACLD actual tactical short-term harvest plans. The modeling exercises for the project were based on ACLD GIS data. For the CCX process, the stand data were used to simulate the ACLD "business as usual" (BAU) tactical harvest plans from 2009 to 2017. Harvest practices were modeled by cover type (total ha) and harvest intensity class (Figure 2). To model harvest activity, we randomly chose stands for harvest based on harvest decision rules that included minimum area, minimum stand age, and minimum basal area (Table 2). Target residual basal areas were modeled on the basis of historical means measured in the field post harvest by ACLD. We calculated carbon stock change from 2009 to 2017 and reported carbon volumes based on whole tree allometric expansion factors (Jenkins et al. 2003). The carbon stock change from 2009 to 2017 represents the potential eligible carbon under the CCX standard.

VCS Eligibility

Determining eligibility under the VCS requires the definition of BAU and alternate forest management scenarios under the Improved Forest Management (IFM) category (Voluntary Carbon Standard 2008). ACLD manages annual

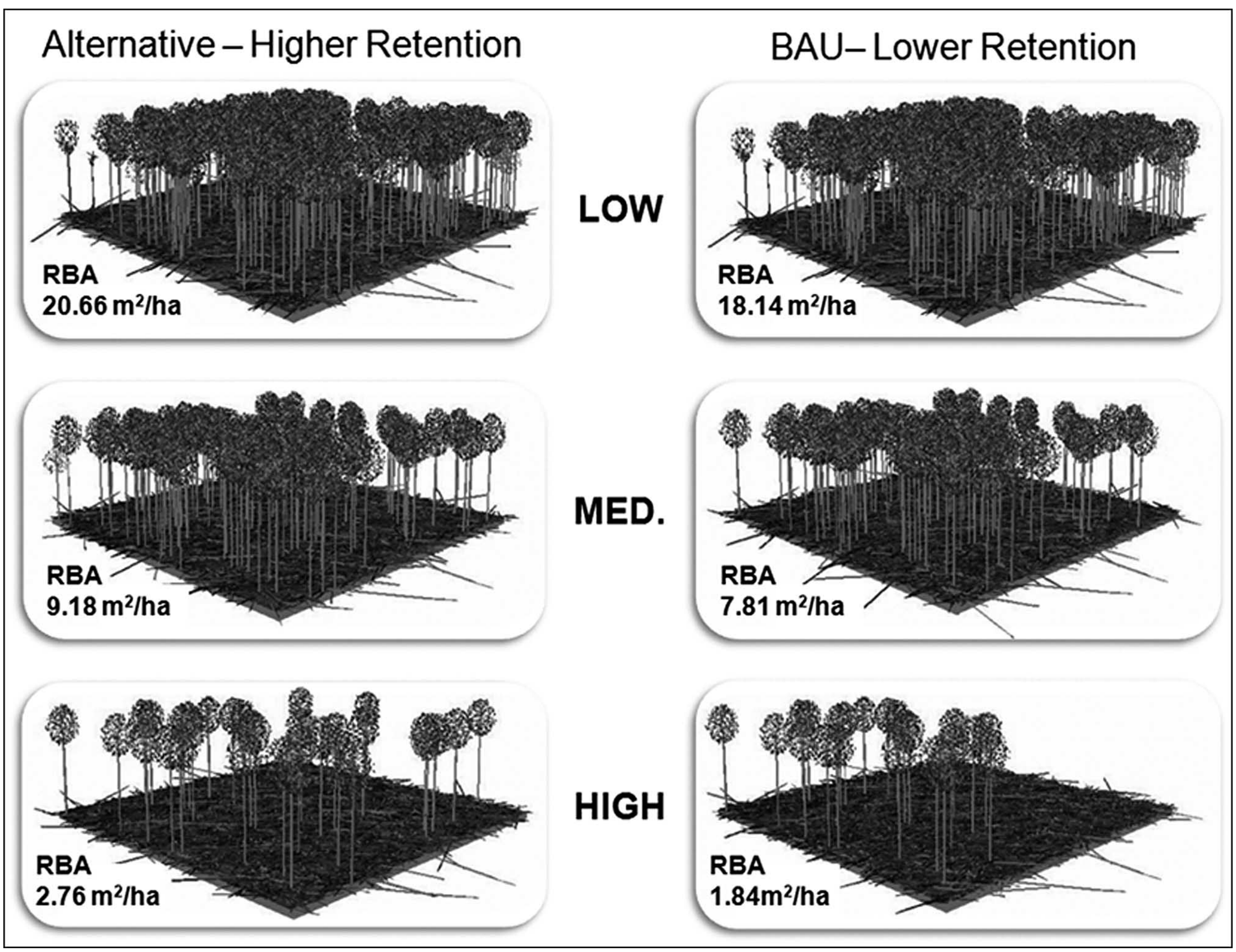

Figure 2. FVS model visualization of a sample Aspen cover type BAU and alternate management scenarios.

Table 2. **Harvest decision rules used to determine eligible stands for simulated harvests using the Forest Vegetation Simulator.**

CSA cover type	Harvest intensity	Minimum basal area (m^2/ha)	Minimum area (ha)	Stand age (yr)	Silvicultural strategy
Ash and lowland hardwoods	High				
	Medium	17	2	100	Regeneration
	Low	28	2	70	Crop tree release
Aspen	High	11	2	50	Regeneration
	Medium	17	2	50	favor long-lived species (tolerant hardwoods)
	Low	28	8	25	Crop tree release
Balsam fir	High	11	2	60	Regeneration
	Medium				
	Low				
Birch	High	11	2	60	Regeneration
	Medium				
	Low				
Black spruce	High	11	2	100	Regeneration
	Medium				
	Low				
Jack pine	High	11	2	50	Regeneration
	Medium				
	Low				
Northern hardwoods	High	11	2	75	Regeneration
	Medium	17	2	75	Regeneration
	Low	28	2	50	Crop tree release
Norway pine	High				
	Medium				
	Low	28	2	25	Crop tree release
Oak	High				
	Medium	17	2	75	Regeneration
	Low	28	2	50	Crop tree release
Tamarack	High	11	2	100	Regeneration
	Medium				
	Low				
White spruce	High				
	Medium				
	Low	28	2	30	Crop tree release

Decision rules are based on the ACLD management plan.
CSA, cooperative stand assessment.

harvest levels based on an area regulation approach designed to create a desired future condition (e.g., balanced age classes and the creation of mixed-species, multiaged stands). We determined that the most effective way to manage carbon stocking in this management regime is to shift harvest practices to lower intensity entries and retain higher residual basal areas where possible and silviculturally valid. We defined baseline harvest intensity by considering ACLD's short-range tactical plans (which are based on the long-term strategic plans). The planned distribution of harvests by cover type and intensity class (high, medium, and low) (Figure 2) then became the BAU for use in the calculation of eligible carbon under the VCS IFM category. The modeling exercises for the VCS process included simulating "alternate" tactical harvest plans and comparing the outcomes to BAU results for 2008 to 2017. The ACLD managers defined realistic alternate management scenarios based on shifts in intensity they believed were achievable and socially acceptable in the region. The choice of alternate management scenarios was subjective but based on the professional judgment of ACLD managers and represents a reasonable option for landowners in this region. Drastic reductions in harvest volumes would be socially unacceptable for mills and loggers in the region, as well as potentially harmful to county revenue. In addition, a significant decrease in harvest volumes has implications for the degree of leakage likely to occur as a result of the change in practices. VCS requires an evaluation of the leakage risk based on the reduction of harvest volume and the likelihood that this volume would simply be harvested elsewhere and thus leaked. Table 3 describes the BAU and alternate management harvest scenarios for ACLD. The percentage of the total annual harvest acreage in each harvest intensity

Table 3. **Harvest treatments used in the simulation of business as usual (BAU) and alternate management scenarios in forest vegetation simulator (FVS) model runs using Aitkin County Land Department stand inventory data.**

Treatment intensity class	Treatment type (RBA range)	Mean BAU RBA	Target alternate RBA
	. . . . (m^2/ha)	. . . .	
High	Clearcut (0–4)	1.84	2.76
Med	Partial harvest (5–11)	7.81	9.18
Low	Select/thin (>11)	18.14	20.66

BAU residual basal area (RBA) is based on mean RBA determined from postharvest evaluations. Both BAU and target Alternative RBA were used in the FVS harvest simulations.

Table 4. Mean residual carbon coefficient matrix for Aitkin County Land Department cover types under base (unmanaged), business as usual (BAU), and alternate management scenarios.

	1: Ash[a]	9: Lowland hardwood	12: Aspen	13: Birch	20: Northern hardwood	30: Oak	50: Pine	61: White spruce	62: Balsam fir	71: Black spruce	72: Tamarack
	(MTC/ha)										
Untreated base[b]	9.44 (0.25)	10.49 (0.73)	9.00 (0.09)	9.03 (0.22)	10.26 (0.15)	12.61 (0.23)	7.13 (0.35)	4.98 (0.54)	6.27 (0.42)	7.16 (0.56)	8.69 (0.53)
High intensity BAU	0.80 (0.01)	0.83 (0.04)	0.84 (0.01)	0.92 (0.01)	0.97 (0.01)	1.10 (0.01)	0.64 (0.02)	0.56 (0.03)	0.77 (0.03)	0.71 (0.04)	0.75 (0.01)
Medium intensity BAU	3.37 (0.04)	3.73 (0.18)	3.45 (0.02)	3.90 (0.05)	4.05 (0.06)	4.76 (0.04)	2.51 (0.09)	2.05 (0.17)	3.04 (0.13)	2.99 (0.16)	3.19 (0.05)
Low intensity BAU	7.69 (0.07)	8.66 (0.22)	7.75 (0.05)	8.13 (0.15)	9.02 (0.11)	10.67 (0.13)	5.28 (0.22)	4.10 (0.39)	5.65 (0.32)	6.08 (0.37)	6.78 (0.22)
High intensity alternate	1.20 (0.02)	1.26 (0.06)	1.25 (0.01)	1.38 (0.02)	1.46 (0.02)	1.67 (0.02)	0.94 (0.03)	0.80 (0.05)	1.14 (0.05)	1.06 (0.06)	1.12 (0.02)
Medium intensity alternate	3.96 (0.04)	4.39 (0.21)	4.05 (0.03)	4.56 (0.06)	4.73 (0.07)	5.60 (0.05)	2.91 (0.11)	2.37 (0.2)	3.51 (0.16)	3.50 (0.19)	3.75 (0.06)
Low intensity alternate	8.41 (0.10)	9.43 (0.25)	8.40 (0.06)	8.65 (0.18)	9.72 (0.12)	11.61 (0.16)	5.82 (0.25)	4.43 (0.44)	5.94 (0.35)	6.51 (0.43)	7.29 (0.28)

Data are mean residual C (SE) derived from forest vegetation simulator model runs
[a] Numbers indicate cooperative stand assessment type. Cover types are ash (dominated by *Fraxinus* spp.), lowland hardwood (dominated by *Fraxinus* spp., *Salix* spp., and *Acer rubrum*), aspen (dominated by *Populus* spp.), birch (dominated by *Betula* spp.), Northern hardwood (dominated by *Acer rubrum*, *Acer saccharum*, *Fagus grandifolia*, and *Quercus rubra*), oak (dominated by *Quercus* spp.), pine (dominated by *Pinus banksiana*, *Pinus resinosa*, and *Pinus strobus*), white spruce (dominated by *Picea glauca*), balsam fir (dominated by *Abies balsamea*), black spruce (dominated by *Picea mariana*), and tamarack (dominated by *Larix laricinea*).
[b] Stands that meet the minimum harvest entry requirements.

category is the important factor to consider. The intent is to shift from higher to lower intensity practices, thereby increasing overall retention of biomass (i.e., carbon). The harvest decision rules used in the model are the same as those described above for CCX. We compared the difference in carbon stock changes between BAU and alternate model runs from 2009 to 2017.

Forest Carbon Stock Estimation

Tree growth was projected using the Lake States variant of the FVS model (Miner et al. 1988, Crookston and Dixon 2005). The ACLD stand-level inventory data was in summary form and did not contain the detailed tree list raw data generated from the timber inventory. Although the stand data were converted to emulate an average tree list for the stand, this conversion did not capture the complexity of actual stands through the simulation of a realistic diameter distribution within species. Over time this diameter distribution would be emulated as growth and mortality is expressed at the stand level. This limitation of the data was not considered to be a major failure of the model because the comparison of different management scenarios is the most valuable part of this exercise.

We then simulated forest growth and carbon stock changes using FVS. Each stand for a given land cover type underwent a total of seven simulations including no harvest, BAU management for three intensity classes, and alternate management for three intensity classes. Individual stands were tagged for possible treatment using minimum starting basal area, age, and size criteria specific to cover type. Treatments were implemented using the standard FVS "treatment from below" option driven by a specific residual basal area consistent with the management option. Results were summarized by treatment and land cover type and their normalized distributions were developed into a matrix (Table 4).

The modeling capability of FVS has proven not to be up to the task of projecting and managing the more than 30,000 stand records. The software crashed repeatedly when we attempted to perform a complete analysis. Because of this technical hurdle, we ran representative sample harvests and growth projections rather than running data for every stand. The BAU and alternate management runs were computed on the basis of the same set of matching stands to minimize bias associated with stand choice. The remaining "no harvest" stands were selected randomly based on a lookup table linkage to the primary stand database. The FVS Lake States Variant does not add regeneration elements by default (except for stump sprouting for appropriate species after harvest). In our analyses, this would only affect the carbon stock change calculations under CCX. However, the short time frame ($<$10 years) we used minimizes the influence regeneration would have on total carbon stocks. Evaluation of longer time scales would indeed require user-defined regeneration inputs (e.g., Nunery and Keeton 2010). However, the absence of regeneration inputs does not influence the results described below because it is based on immediate pre- and post-harvest carbon stocks and not the flow of carbon stocks over time.

We analyzed 5,537 stands representing 22,545 ha in Aitkin County. This provided a very large sample size to conduct meaningful analyses. Mean (and SD) aboveground live carbon and mean (and SD) belowground live carbon were computed for each variable combination (e.g., county, cover type, management scenario, and treatment). Total stand carbon values were suspect because of the inclusion of standing dead carbon and dead downed wood carbon values that were well outside the range of those reported by Smith et al. (2006). Aboveground live and belowground live carbon values reported were within the range expected for stands in the Lake States region (Smith et al. 2006).

We developed a spreadsheet-based matrix to calculate carbon stock values under differing BAU and alternate management scenarios for three harvest intensity classes and each of the 11 land cover types (Table 2). Mean carbon values from Table 4 were expanded by the total ha of each cover type in the BAU and alternate management scenarios. These carbon stock values were then used to estimate carbon additionality (alternate management minus BAU). The calculation of carbon stock values consists of three major steps. The first step was to parameterize the matrix with the mean residual carbon distributions for each land cover type from the FVS modeling results. The second step was to determine the total area by land cover type and harvest intensity class under both the BAU and alternate management strategies. The area matrix is then normalized with harvest-eligible untreated areas (base) by land cover type. In the final step, we determined carbon additionality by multiplying the area by the residual carbon coefficients for each of the base, BAU, and alternate land cover classes and subtracting the BAU. We made the assumption that the normalized area under study is static with no associated variation and that the residual carbon coefficients have a normal distribution defined by the SE calculated from the FVS results. The additionality calculation is then implemented 1,000 times across the land cover and harvest intensity matrix where the residual carbon coefficient is randomly selected from the defined normal distribution. The results are summarized to estimate carbon additionality and associated SE.

Results

CCX Eligibility

The mean net annual carbon stocking during the period 2009–2017 for ACLD lands was 4,807,913 million tonnes carbon (MTC), which represents a loss of 579,943 MTC from the starting value of 5,387,856 MTC in 2009 (Figure 3). These values represent the total carbon stock change on ACLD lands under the modeled BAU scenario (aboveground and belowground biomass in unmanaged forest and BAU harvested stands) for the 2009–2017 time period. Eligibility under CCX requires an accumulation of carbon stocks over a base year value (here, 2009). Under this management scenario and the fluctuating carbon stocks, ACLD would not be able to claim eligible carbon for sale as credits under CCX.

VCS Eligibility

The difference between residual carbon values in the alternate minus BAU management scenarios represents the eligible carbon under VCS. Annual VCS eligibility was 20,832 MTC (SE = 973 MTC) under the shift in harvest intensity and total acreage described in Table 1 and expanded by the C coefficient matrix (Table 4). This equates to roughly 0.23 MTC/ha (based on 89,840 ha total ACLD ownership) or 11.97 metric tonnes carbon dioxide equivalent per managed ha (assuming 1,740 ha under management influence, harvest, or forgone harvest).

Discussion

Carbon Eligibility

Based on the mean negative annual carbon accumulation demonstrated under the CCX scenario, it seems unlikely that either land manager could maintain a positive carbon balance for sale on the CCX trading platform while meeting other management objectives. The carbon stock change rates for each county would be expected to vary significantly given the area regulation strategy used by ACLD. Volume removed will vary widely depending on stocking in stands chosen for harvest to achieve the desired future

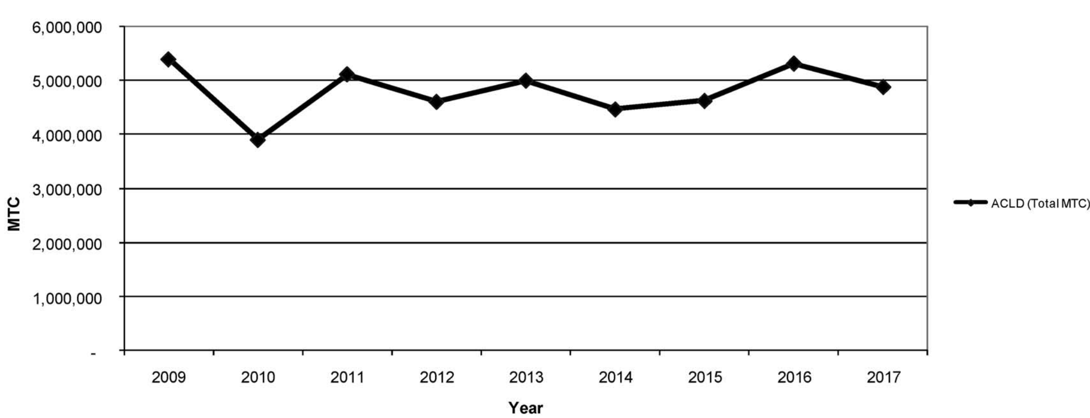

Figure 3. Total annual carbon stocks (MTC) for ACLD. The annual net change in carbon stocks represents the potential eligible carbon credits to be claimed using the CCX forest offset standards.

condition. Figure 3 indeed shows this fluctuation in standing live carbon volume. High-intensity harvest activity has a significant impact on the carbon budget. These harvests were concentrated in the aspen (*Populus* spp.), Northern hardwood, and balsam fir (*Abies balsamea*) in Aitkin County. The CCX standard requires a net increase of carbon stocking over time, which may create periods of time where eligible carbon volume would be low or even negative. The county would need to replace any carbon losses during the life of the project. In addition, CCX requires that 20% of the total eligible carbon be set aside to guard against catastrophic disturbances.

The VCS IFM category that allows for comparison against a baseline case (BAU) appears to create more opportunity for landowners managing under area regulation to engage in carbon markets. However, the amount of eligibility is proportional to the degree of change in practices and on a per ha basis, it may not be significant for small ownerships. Larger ownerships could realize more significant benefit under the VCS by modifying practices to favor lower intensity practices. ACLD chose a conservative modification of practices to minimize the potential impacts on timber harvest volume. This factor was considered important because of the landowner's role in wood supply for the region. The VCS also views this favorably by not penalizing projects such as this that minimize the risk of leakage. Leakage occurs when a project simply causes emissions to shift to another location. In the case of timber harvesting, this means the forgone volume from a carbon offset project would be taken up by another landowner in the same wood supply region or even elsewhere globally. A minimal reduction in harvest volume is therefore desirable from a landowner and a carbon market's point of view to minimize the leakage impacts of a project. Too much harvest volume reduction would result in a large discount of the eligible carbon.

Defining BAU is the determining factor for eligibility under VCS. For this project, evidence was available in the form of approved management plans and a documented management history that could be used to justify a choice of BAU scenarios. For many landowners, this level of documentation and past management data may not be readily available. The lack of information to support the definition of a BAU can be a limiting factor in carbon project development. Defining BAU at a regional/nonproject scale would be beneficial for increasing landowner participation in carbon projects, including landowners such as ACLD who have been practicing responsible forest management for many years. In fact, ACLD has been third-party certified under the Forest Stewardship Council standards since 1997. Given the Forest Stewardship Council standards that landowners must adhere to (verified via annual audits), it is likely that they are already practicing lower intensity and higher retention harvesting than typical landowners in the region. Although the VCS standard requires that a project-specific BAU is developed, ACLD is clearly providing greater carbon sequestration benefits than are credited under the standard. To demonstrate this, a theoretical BAU definition was developed based on Minnesota statewide practices as reported in Puettmann and Ek (1999). The 1996 survey is the most recent data available to define BAU for landowners in the state. Under this statewide BAU, harvest activity is skewed toward high-intensity practices such as clearcutting with little retention (Table 5). When the ACLD alternate scenario is compared with the statewide BAU (Table 5), carbon credit eligibility nearly doubles to 34,008 MTC (SE = 1,225 MTC). Clearly, a standard that recognizes a regional BAU or baseline would create advantages for those already practicing forest management that is beneficial to carbon storage onsite. Without the establishment of a regional BAU, Minnesota's forest landowners and managers will need high-quality inventory and historic growth and removal data to establish their own regional practices baseline. The need to establish this baseline will be a limiting factor in a landowner's ability to successfully develop a carbon offset project. Baseline establishment could be simplified if a regulatory or statewide data source existed that provided a more universal and current baseline for forest practices in Minnesota. Acceptance for this type of baseline definition is growing as evidenced by the recent release of the draft Climate Action Reserve Forest Offset Protocol (Climate Action Reserve 2010) that allows baseline to be defined by the mean carbon stocking for the given forest type and region (based on US Forest Service Forest Inventory and Analysis data).

Table 5. Theoretical business as usual (BAU) harvest intensity scenario based on Minnesota statewide historical harvest activity.

Harvest intensity	Historical BAU (1996 statewide)	Alternate management scenario
	. . . . (% of total harvest)	
High	87%	35%
Medium	1%	12%
Low	12%	53%

Data from Puettmann and Ek (1999). The alternate management scenario was proposed by Aitkin County Land Department land managers.

Management Implications

Shifting harvest intensity (where appropriate) to lower-intensity practices results in greater retention (i.e., higher residual basal area) and therefore also increases carbon storage onsite. Forest managers using an area regulation approach to achieve silvicultural or ecological objectives will have opportunities to claim carbon credits if the carbon marketplace continues to recognize a BAU baseline definition at either project or regional scales. If federal policy moves toward a standard such as CCX that favors a volume-based management approach, then conceivably a high-price carbon marketplace could drive management away from area regulation and potentially compromise other ecological objectives.

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