Minnesota North Woods Carbon Credit Partnership

Project Report – Executive summary

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Project Partners:
Aitkin County Land Department
Cass County Land Department
Dovetail Partners, Inc.
Manomet Center for Conservation Sciences

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Introduction

The goal of the *Minnesota North Woods Carbon Credit Partnership* is to develop a carbon credit accounting system that works for Minnesota's North Woods, including considerations for carbon storage associated with active forest management, long-lived wood products, and peatland restoration and management. The project was developed to meet the requirements of the Chicago Climate Exchange (CCX) and the Voluntary Carbon Standard (VCS). The project utilized existing forest inventory and growth and yield data for the region, including information collected by the Forest Inventory and Analysis (FIA) Program of the U.S. Forest Service and data from the Aitkin and Cass County Land Departments.

The *Minnesota North Woods Carbon Credit Partnership* was developed with the participation of Aitkin County Land Department, Cass County Land Department, Dovetail Partners, Manomet Center for Conservation Sciences, and the USDA Forest Service. The county land departments and the USDA Forest Service had primary responsibilities for providing data as necessary to support growth models and carbon credit accounting systems. The Manomet Center for Conservation Sciences had lead responsibilities for crafting a carbon credit framework that fits the requirements of the marketplace while meeting the goals of the land managers of Minnesota's North Woods.

The approach outlined by the project can be used to develop estimates of carbon storage potentials. With this information land managers can then complete a third-party audit to confirm the carbon credits and allow them to be marketed. Many of the large land mangers in Minnesota are already participating in third-party forest certification and many of the same auditors can provide carbon credit auditing services. The project has been piloted with the Aitkin and Cass County Land Departments and the approach taken by these counties is being made available for use by other public and private land managers.

The overall goal of the project has been to establish a system that will result in carbon credits being sold from Minnesota's Northwoods. The mid-term strategy is to promote the system and demonstrate its utility so that further adoption occurs and carbon markets in Minnesota can be expanded. Over the long-term, additional ecosystem service markets will be pursued that can be easily "layered" on top of the carbon credit framework and expand the economic and environmental benefits to the region.

Project Context

There are increasing opportunities for market-based mechanisms to support responsible forestry and environmentally beneficial land use decisions. These opportunities are linked with the growing interest in global warming, climate change, and the influence that human activities have on our environment. An increasingly common market-based mechanism is the "carbon credit" which links marketplace values with the sequestration of carbon. Additional market opportunities for other ecosystem products and services include payments for water quality credits, soil protection, and habitat enhancements. Based upon international agreements, there are at least four broad categories of established ecosystem services: carbon sequestration, water and wetlands, biodiversity and wildlife, and landscape aesthetics or ecotourism. By one count, there are currently more than 300 markets for ecosystem services operating around the world.

The leading international framework for ecosystem services is the United Nations Framework Convention on Climate Change (UNFCCC) that was signed at the 1992 Earth Summit. Since that time, 192 counties have ratified the Convention, including the United States. The UNFCCC includes two important pieces, the Convention on Biological Diversity and the Kyoto Protocol. The Convention on Biological Diversity provides a structure for biodiversity related ecosystem services, and the Kyoto Protocol provides the leading opportunities for carbon sequestration markets.

Within the Kyoto Protocol there are three "mechanisms" that create cap-and-trade models and are the basis of the mainstream carbon market. The mechanisms include Emissions Trading, Joint Implementation, and Clean Development. The Clean Development Mechanism (CDM) is referenced most frequently and is distinguished by its focus on carbon credits that result from financing carbon reduction projects in developing countries. In 2006, CDM traded credits totaled $5 billion (USD) and accounted for 450 million tons of reduced carbon dioxide emissions ($MtCo_2e$).

The United States has not ratified the Kyoto Protocol; however, individual states and regions within the country have organized systems for participating in the global carbon market. The U.S. carbon market has developed on a primarily voluntary basis. Forestry-based carbon projects have been an important component in this market. There are four leading mechanisms currently operating in the U.S. that allow participation in the carbon market, including the Chicago Climate Exchange, the Department of Energy's National Voluntary Reporting of Greenhouse Gases Program, the California Climate Action Registry (CCAR) and Climate Action Reserve, and the Regional Greenhouse Gas Initiative (RGGI).

The first regulation of carbon dioxide in the United States occurred in Oregon in 1997 when new power plants were required to reduce their emissions directly, through offsets, or through payments to The Climate Trust, a non-profit created to implement CO_2 offset projects. Trading in greenhouse gas (GHG) emissions has been occurring in the U.S. since 2003. There are increasing calls for a national system of greenhouse gas (GHG) regulation in the United States to allow for more comprehensive and consistent participation.

In addition to carbon and GHG cap-and-trade systems, markets for ecosystem services include interests in water quality, water source protections, habitat, and biodiversity; and work in theses areas is occurring in Minnesota. Minnesota has been active in the development of water quality trading rules, including efforts by the Minnesota Pollution Control Agency and active projects in the Minnesota River Valley. Research to expand the program is continuing in 2009. There are also opportunities in Minnesota to explore carbon storage and ecosystem benefits associated with peatlands. According to a report prepared by the Minnesota Terrestrial Carbon Sequestration Initiative, total carbon stocks in peatlands in Minnesota are eight times greater than the forest-based carbon stocks.

Many organizations, including the University of Minnesota and the Minnesota Department of Natural Resources have been active in carbon credit and climate change projects and research in the state. The Minnesota Climate Change Advisory Group (MCCAG) and the University of Minnesota's Terrestrial Carbon Sequestration Initiative have identified key strategies and recommendations for reducing and offsetting carbon emissions and provide important context for the *North Woods Carbon Credit Partnership*.

Methods and Analysis

A core objective of the *Minnesota North Woods Carbon Credit Partnership* is to provide a case study that is of potential value for marketing managed forest offsets and to those who are seeking possible mechanisms to recognize forest management offsets. The project demonstrates how forest management in Minnesota can sequester additional carbon. Project partners have focused on particular stand types and conditions, and the modeling considers carbon outcomes based on the timing and intensity of treatments across these different conditions. The treatment modifications are conservative and based on what the partners believed were realistic opportunities for modification of management practices. The data can be re-evaluated as needed based on management plan updates and re-inventory.

For all forest carbon offset protocols, a detailed and statistically rigorous forest inventory is required to establish the volume of carbon present at the start of the project and subsequently to verify accumulated carbon volume throughout the life of the project. The existing forest carbon protocols have varying requirements for what pools of carbon are allowed as creditable carbon. We used stand-level inventory data already in use by the County Land Departments as the basis for analysis and growth models. For the project, the Aitkin County Land Department (ACLD) and Cass County Land Department (CCLD) provided inventory and removal data summaries for the years 1997-2007. The stand inventory data are based on the Cooperative Stand Assessment (CSA) forest stand mapping and information system used by the Minnesota Department of Natural Resources (DNR). The CSA inventory is a stand-level inventory that provides information on cover type, stand size, stocking, composition, stand age, health and condition, and some measures of site productivity. The CSA data were adequate for the analyses described below particularly because the primary interest is in understanding the relative difference in carbon accumulation under different management scenarios.

The counties also provided GIS data layers and prepared the datasets for model exercises using the Lake States Variant of the USFS Forest Vegetation Simulator (FVS). Each county provided summaries of forest inventory stocking levels from 1997-2007 to establish a historical baseline condition. Additionally, harvest data were provided for the same time period to allow the evaluation of historical harvest activity levels. Strategic (long-term) and tactical (2008-2010) management plans were provided to describe management objectives (by intensity class and cover type) and to define current silvicultural practices appropriate for each cover type. Quantitative silvicultural prescription data (e.g., mean starting basal area, mean residual basal area) were provided by ACLD from post-harvest data collected from 1997-2007. These data were important for use in the modeling of harvest scenarios for both counties.

The objective of the forest carbon modeling was to develop a verifiable estimate of the carbon sequestration potential of the stands. Such an approach is generally required by the predominant carbon verification systems (e.g., CCX and CCAR). The project partners also sought to develop an information-efficient framework for assigning carbon valuation to stands similar in size, composition and productivity to those in the pilot project. Data are summarized based on the common cover type designations use in the CSA. The intent was to develop simulations based on readily available, accessible, and accepted models that depend on easily acquired inventory data. The models should be flexible enough to allow generalization to properties and stands not included in the initial inventory (i.e., for future expansion of the pilot project).

The tree growth simulation model for the project was the USFS Forest Vegetation Simulator (FVS), with the Lake States Variant.

Developed by the Forest Service and widely used, the Forest Vegetation Simulator (FVS) is an individual tree, distance independent growth and yield model with linkable modules called extensions, which simulate various insect and pathogen impacts, fire effects, fuel loading, snag dynamics, and development of understory tree vegetation. FVS can simulate a wide variety of forest types, stand structures, and pure or mixed species stands and allows for the modeling of density dependent factors. The Lake States (LS) variant was developed in 1993 using relationships from the LS-TWIGS model (Miner and others 1988), and equations from other variants for FVS relationships not present in LS-TWIGS. Since the variant's completion in 1993, some of the functions have been adjusted and improved as more data has become available, and as model technology has advanced.

The ACLD and CCLD stand-level inventory data was in summary form and did not contain the detailed tree list raw data generated from the timber inventory. While the stand data was converted to emulate an average tree list for the stand, it still 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. We did not consider this to be a major failure of the model since the comparison of different management scenarios is the most valuable part of this exercise. FVS-LS estimates also need to be evaluated to ensure that ingrowth is properly captured. Regeneration is included in the FVS LS Variant; however, it should be verified with known regeneration standards for the different cover types.

The project design included several assumptions and considerations.

- Shifting Harvest Intensity (where appropriate) to lower Intensity categories results in greater retention, therefore also increased carbon benefit.
- Increasing Mean Residual Basal Area (RBA) for treatment types will also increase carbon benefit
- Future analysis will also evaluate the implications of creating additional set aside acres and increasing riparian buffer widths

To complete the modeling exercise, the counties provided the following management information:

- Harvest decision rule thresholds (e.g., minimum stand BA for treatment, minimum volume, minimum stand acreage for treatment)
- Harvest decision rules for choice of treatment within Harvest Intensity Categories (e.g., clearcut vs. clearcut with residuals)
- BAU and Alternate Treatment acreage breakdown by cover type within each Harvest Intensity category (e.g., X acres Treatment 1, X acres Treatment 2 within "High Intensity")
- Defined acceptable Alternate Harvest Intensity Rules based on realistic opportunities for shifting Harvest Intensity categories and RBA
- Tactical Plans for the entire time period to be modeled (e.g., 2008-2017)
- Riparian modification table illustrating how riparian area treatments are applied.

The modeling capability of FVS proved not to be up to the task of projecting and managing the more than 30,000 stand records for the two counties combined. The model crashed repeatedly when attempting to perform a complete analysis. Because of this technical hurdle, we decided to run representative sample harvests and growth projections rather than conduct a run that included every stand. The BAU and ALT harvest runs were computed based upon the same set of overlapping stands to minimize bias associated with stand choice. The remaining “no harvest” stands were selected randomly based upon a lookup table linkage to the primary stand database.

In total, 5,537 stands were analyzed, representing 55,688 acres in Aitkin County, and 61,016 acres in Cass County. We believe this provided a very large sample size to conduct meaningful analyses. Mean (and Standard Deviation) Aboveground Live Carbon and Mean (and Standard Deviation) 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, 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). Data on harvest removals from the different Treatment and Cover Type combinations were set aside for further economic analyses. Mean carbon values were then expanded by the acreage figures for each Cover Type in the BAU and ALT harvest scenarios.

The only harvest intensity where the residual basal area (RBA) was modified was the High Intensity category. The residual live carbon biomass values for both harvest scenarios (BAU and ALT) were not significantly different (t-test, $p>0.05$) and made the distinction of modifying the residual basal area meaningless in terms of impact on the carbon budget. Two square feet per acre basal area was simply too minor a change to account for a non-linear relationship between carbon volume and tree basal area.

Table 1. Harvest Decision Rules Used in FVS Models

CSA Cover Type	**Harvest Intensity**	**Min harvest BA (stocking)**	**Min Harvest Acreage**	**Stand Age**	**Silvicultural Strategy**
Ash and Lowland Hdwds	High				
	Medium	75	5	100	regeneration
	Low	120	5	70	crop tree release
Aspen	High	50	5	50	regeneration
	Medium	75	5	50	favor long-lived species (tolerant hardwoods)
	Low	120	20	25	crop tree release
Balsam Fir	High	50	5	60	regeneration
	Medium				
	Low				
Birch	High	50	5	60	regeneration
	Medium				
	Low				
Black Spruce	High	50	5	100	regeneration
	Medium				
	Low				
Jack Pine	High	50	5	50	regeneration
	Medium				
	Low				
Northern Hdwds	High	50	5	75	regeneration
	Medium	75	5	75	regeneration
	Low	120	5	50	crop tree release
Norway Pine	High				
	Medium				
	Low	120	5	25	crop tree release
Oak	High				
	Medium	75	5	75	regeneration
	Low	120	5	50	crop tree release
Tamarack	High	50	5	100	regeneration
	Medium				
	Low				
White Spruce	High				
	Medium				
	Low	120	5	30	crop tree release

Chicago Climate Exchange (CCX) Process

CCX defines eligible carbon simply as the net accumulation of carbon stocks over time. 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 FVS LS Variant is an approved model under the CCX requirements. Therefore, to determine eligible carbon through the CCX process, we used the FVS model to "grow" the current inventory (2008) for 10 years while implementing a planned harvest regime for each county based upon their actual tactical short-term harvest plans. The modeling exercises for the project were based on ACLD and CCLD stand-level inventory GIS data. For the CCX process, the stand data were used to simulate the "business as usual" (BAU) tactical harvest plans 2008-2017 for both Land Departments. Harvest practices were modeled by Cover Type (total acres) and Harvest Intensity class (high, medium and low). High intensity harvest retains less than 20 square feet basal area; medium intensity retains 20 to 49 square feet basal are; and low intensity retains 50 square feet or more basal area.

To model harvest activity, we randomly chose stands for harvest based on harvest decision rules that included minimum acreage, minimum stand age, and minimum basal area (Table 1.). Target residual basal areas (RBA) were modeled based on historical means measured in the field post harvest by ACLD. We calculated carbon stock change from 2008-2017 and reported carbon volumes based on *whole tree allometric expansion factors* (Jenkins et al. 2003), not just merchantable volume. The carbon stock change from 2008-2018 represents the potential eligible carbon under the CCX standard.

Voluntary Carbon Standard (VCS) Process

The *VCS Guidance for Agriculture, Forestry and Other Land Use Projects* states:

"Project developers using a project-based approach (rather than a performance benchmark) for establishing a baseline must provide the following information to prove that they meet minimum baseline standards for improved forest management projects:

- *A documented history of the operator (e.g., operator must have 5 to 10 years of management records to show normal historical practices). Common records would include data on timber cruise volumes, inventory levels, harvest levels, etc. on the property; and*
- *The legal requirements for forest management and land use in the area; however if these are not enforced then this requirement does not have to be met; and*
- *Proof that their environmental practices equal or exceed those commonly considered a minimum standard among similar landowners in the area.*

The baseline for the IFM project is then the without-project management practices projected through the life of the carbon project, satisfying at a minimum the three standards given above."

To determine eligible carbon through the VCS process, we evaluated the 10 Year ACLD/CCLD harvest and inventory data and worked with the Land Departments to determine cover types where opportunities exist for "improved forest management (IFM)" practices to be modified. We then modeled the impacts of management changes on carbon stocks in the selected types for a 10 year period (2008-2017) and calculated "leakage" risk associated with potential reduction in harvest volumes (Table 3). Ten years was chosen because it represents a reasonable time frame to plan harvest activities and allows a reasonable projection of growth within a model. Longer time periods are associated with greater degrees of uncertainty both in the models and in planned activities.

Both ACLD and CCLD manage annual 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, multi-aged 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 each Land Department's short-range tactical plans (which are based upon the long-term strategic plans). The planned distribution of harvests by cover type and intensity class (high, med, and low) then became the BAU for use in the calculation of eligible carbon under the VCS. The resulting carbon balance of the BAU model is the same scenario used to demonstrate eligible carbon under the CCX standard.

Table 2. VCS Baseline requirements.

Within the VCS process, establishing a baseline requires the following information to prove that minimum acceptable standards are met:	**ACLD and CCLD Evidence**
A documented history of the operator (e.g., operator shall have 5 to 10 years of management records to show normal historical practices). Common records would include data on timber cruise volumes, inventory levels, harvest levels, etc. on the property;	Inventory summary data were evaluated for 1997, 2002, and 2007. Removal data were summarized for 1997-20007.
The legal requirements for forest management and land use in the area, unless verifiable evidence can be provided demonstrating that common practice in the area does not adhere to such requirements; and	Both CCLD and ACLD are third-party certified to the Forest Stewardship Council (FSC) forest management standard which verifies that legal requirements for forest management and land use in the region are being met.
Proof that their environmental practices equal or exceed those commonly considered a minimum standard among similar landowners in the area.	Both CCLD and ACLD are third-party certified to the Forest Stewardship Council (FSC) forest management standard which verifies that legal requirements for forest management and land use in the region are being met.
The baseline for the IFM project is then the management practices projected through the life of the project, satisfying at a minimum the three requirements mentioned above.	The allocation of harvest acreage by intensity class based upon the Tactical Plans was used to project baseline management practices through the life of the project (10 years). Harvest intensity was defined using field data collected by ACLD to determine

Table 3. VCS Leakage Assessment

Project Action	Leakage Risk	Leakage Credit Adjustment
Reduced impact logging with no effect or minimal effect on total timber harvest volumes	None	0
Extend rotations moderately (5-10 years) leading to a shift in harvests across time periods but minimal change in total timber harvest over time	Low	10%
Substantially reduce harvest levels permanently (e.g., forest protection/no logging project, or RIL activity that reduces timber harvest by 25% or more)	Moderate to High	Depends on where timber harvest is likely to be shifted: • Similar carbon dense forests within country: 40% • Less carbon dense forests within country: 20% • More carbon dense forests within country: 70% • Out of country: 0% (according to stated VCS and CDM policy of not accounting for international leakage)

The modeling exercises for the VCS process included simulating “Alternate” tactical harvest plans and comparing the outcomes to “Business as Usual” (BAU) results for 2008-2017. The County Land Managers defined realistic Alternate harvest scenarios based on shifts in intensity they believed were achievable and socially acceptable in the region. This latter point is significant as a major reduction 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 (Table 3.) based on the reduction of harvest volume and the likelihood that this volume would simply be harvested elsewhere and thus “leaked”. It does not appear that the harvest reduction would meet the 25% requirement under VCS to be considered “high risk”.

Tables 4 and 5 describe the BAU and Alternate harvest scenarios. The percent of the total annual harvest acreage in each harvest intensity 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 2008-2017. Future work could include an evaluation of the possibility of modifying the post-harvest residual basal area to a higher retention volume. We chose only to modify the High intensity harvest residual basal area from a mean of 8ft.^{2} per acre to 10ft.^{2} per acre (Table 5).

Table 4. BAU and Alternate Harvest Intensity Summary
(see Tables 8a and 8b for acreage details).

CCLD Harvest Intensity Summary (% of total annual harvest)

	2008-2018	
Harvest Intensity	**BAU**	**Alternate**
High	58%	51%
Medium	28%	28%
Low	12%	20%

ACLD Harvest Intensity Summary (% of total annual harvest)

	Historical	2008-2018	
Harvest Intensity	**1999-2007**	**BAU**	**Alternate**
High	44%	57%	44%
Medium	17%	7%	11%
Low	38%	37%	47%

Table 5. BAU and Alternate Residual Basal Area (RBA) Following Treatment (ft.^{2} per acre)

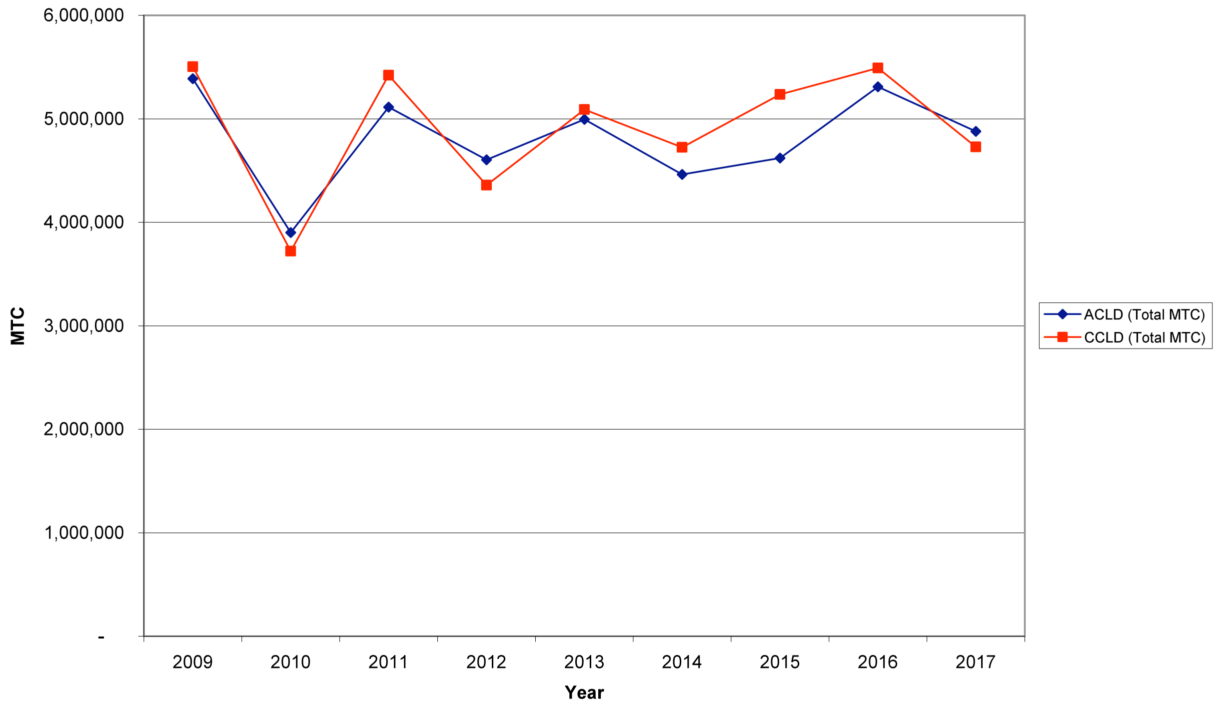
Treatment Intensity Class	Treatment Type	Mean BAU RBA	Alternate RBA
High	Clearcut (RBA 0-19)	8	10
Med	Partial Harvest (RBA 20-49)	34	34
Low	Select/Thin (RBA 50+)	79	79

Results & Findings

Simulation Model Results – Additionality (Creditable Carbon)

Total carbon stock changes (above and below ground biomass) for the 2009-2017 time period is presented in Figure 1 for the two modeled scenarios (ACLD and CCLD, no management plus BAU harvested stands). Stand-level carbon volume snapshots were captured annually and summarized by CSA Cover Type and County. This model run of "no management" stand combined with the BAU harvest runs represented the overall business as usual trajectory that could be used to demonstrate CCX-eligible carbon.

Figure 1. Total Metric Tons of Carbon (aboveground and belowground live) for Aitkin and Cass County Land Departments



CCX

The net annual change in carbon stocking for Cass County for the period was projected to be -97,052 MTC (or an average net loss). The change in Aitkin County was – 63,717 MTC (also a net loss). Based on the negative trend over time, it would be difficult to maintain a positive carbon balance for sale on the CCX trading platform. The carbon stock change rates for each county would be expected to vary significantly given the area regulation strategy of managing harvest rates employed by each county. Volume removed will vary widely depending on stocking in stands chosen for harvest to achieve the desired future condition. Figure 1 indeed shows this fluctuation in standing live carbon volume for both counties. Since the CCX standard requires there to be a net increase of carbon stocking over time, this may create periods of time where eligible carbon volume would be low, or even negative. The counties would need to maintain buffers, or reserves, to replace this carbon during the life of the project. CCX requires that 20% of the total eligible carbon be set aside for such a purpose – or to guard against catastrophic disturbances.

VCS

The Alternate harvest scenario was compared to the BAU scenario to generate eligible carbon under the VCS requirements. Under this modified carbon management scenario, potential carbon accumulation over a 10 year period would be 6,685 MTC – or 24,516 MTCO2e per year for Cass County and 6,169 MTC – or 22,624 MTCO2e per year for Aitkin County.

The VCS requirement of making comparisons to a baseline should be generally advantageous for landowners managing based on area regulation. The annual fluctuations of removal volumes would become irrelevant when you are comparing a modified management regime versus what would have been undertaken in a Business as Usual scenario. It is clear that the VCS standard allows for the management flexibility required to conduct restoration forestry or when dealing with timberland currently in an unregulated (i.e., age class distribution) state. However, the wide variability in starting volumes and residual carbon biomass volumes minimizes the opportunity for carbon increases when a modest shift in harvest intensity is made. Clearly, more dramatic changes would be needed to create large amounts of carbon volume eligible under the VCS requirements. In the cases of both ACLD and CCLD, practicing progressive management with higher retention rates and already a moderate intensity regime could minimize opportunities for carbon credits under the current VCS standard.

The greatest gains in total carbon were made in the Northern Hardwood and Red Pine Cover Types in Aitkin County; and Northern Hardwood and Red Oak cover types where harvest intensity was shifted from High to Medium or Low – and the post-harvest residual basal area was modified from $8ft.^2$ per acre to $10ft.^2$ per acre. However, as noted above, this shift in residual basal area likely had little impact overall. Table 6 shows the relationship between BAU and the Alternate harvest scenario.

Table 6. Annual Residual Live Carbon (aboveground and belowground) in BAU vs. Alternate (ALT) Harvest Scenarios

County	BAU Residual Live Carbon Biomass (MTC)	ALT Residual Live Carbon Biomass (MTC)	VCS Eligible Carbon (MTC)
ACLD	43,846	50,016	6,170
CCLD	45,262	51,947	6,686

No Management Scenario

It is not surprising that the "no management" scenario shows the greatest overall increase in carbon stocking. These projections assume no management and no occurrences of catastrophic disturbances (though typical mortality is included). It is important to note that the rate of biomass accumulation follows a logistic function. The implication is that younger (low basal area) and older (high basal area stands) will grow at slower per capita rates than the middle-aged stands. Clearly, when no removals take place the forest should continue to increase total biomass, which is directly related to carbon volumes. The interesting comparison to make is through the inclusion of long-lived harvested wood products. Next steps in the project will utilize the outputs from the BAU and ALT harvest model runs to evaluate the contribution of harvested wood products to the overall carbon budget of the managed stands by tracking the volume of carbon anticipated to remain in storage at 100 years following removal. The FVS carbon submodel allows these product flows to be tracked and discounted based upon decay rates published by Smith et al. (2006) and used by the US EPA 1605b registry. We will use these figures as they are now widely used and do contain modifications for the Lake States region. We recognize that more refined LCA assumptions could be made, but not without significant investment of resources.

Annual Removals

Outputs from the model runs include data on merchantable material removed to allow for an analysis of the impacts of forgoing harvest revenue versus maintaining residual volume for carbon. Modeling this aspect is critical for a landowner to understand the implication of modifying management practices to benefit carbon storage versus maximizing harvest volume. The market price per MTCO2e is clearly an important factor in making a decision to trade harvest revenue for carbon storage – as is the market price for harvested material. Carbon market price is discussed in more detail below.

The Value of Eligible Carbon

The eligible carbon volumes we report are based on a 10 year projected change in stocking. While these projections are critical for understanding implications of management for carbon offset opportunities, actual carbon sold will need to be verified through periodic inventory updates. The periodicity of re-measurement could vary based on the precision of the initial measurements and the level of harvest activity. Though stock changes could be measured directly post harvest and models could be relied upon for net change in unmanaged stands. Re-measurement requirements for carbon markets would likely be consistent with certification requirements. We present Table 7 to show the potential annual revenue under assumed prices that represent the current reality under both CCX and VCS.

Table 7. Potential Annual Revenue under CCX and VCS Standards for Aitkin and Cass Counties.

County	CCX Eligible MTCO2e (annual)	CCX Potential Revenue (annual) @$2.00/MTCO2e	VCS Eligible MTCO2e (annual)	VCS Potential Revenue (annual) @ $4.00 - $6.00/MTCO2e
CCLD	-97,052 MTC or -355,889 MTCO2e	NA	6,685 MTC or 24,516 MTCO2e	$98,064 – $147,096
ACLD	-63,717 MTC or -233,650 MTCO2e	NA	6,169 MTC or 22,624 MTCO2e	$90,496 - $135,744

Note: 1 MT Carbon = 3.667 MTCO2 equivalent (MTCO2e)
Source: US EPA

Currently, the price for carbon credits is relatively low, but prices may return to or exceed past high values in the future. Past patterns for carbon credit prices show that when gas is expensive, energy producers rely more on coal, which emits higher levels of CO_2 and boosts demand for carbon permits. When fossil fuel is cheap, demand for carbon permits falls. Prices for CCX's Carbon Financial Instruments (CFI), which can only be traded on the CCX platform, have fallen by about half since August 2008, from about \$4.00 to a range closer to \$2.00 today. Credits under the California Climate Action Registry (CCAR) have fluctuated from a high of \$11.00 per ton of CO_2 equivalent to a low of \$7.20 in the last half of 2008. VCS-based instruments traded between \$6.60 per ton and \$4.80 per ton, indicating a fair degree of volatility.

In 2008, voluntary and regulatory carbon markets traded \$118 billion of carbon credits (New Carbon Finance 2009). The global carbon market is predicted to be largely immune to the worst effects of the economic slowdown and could grow to over \$150 billion in 2009. It is likely that "high quality" carbon offset projects will be sold more readily than less rigorous projects.

Next Steps

The full process for landowners considering markets for carbon credits includes the following steps:

1. Providing initial inventory information to determine baseline
2. Proposing possible carbon trajectories for evaluation based on starting point & landowner objectives
3. Commitment to a management plan that incorporates carbon-storage practices and meetings third-party certification standard
4. Carbon-storage is verified through the certification process and eligible to be aggregated with other pool properties & marketed to buyer
5. Agreement signed if price and sale contract terms are acceptable

For Aitkin and Cass County, the next steps include determining whether or not to move forward with having the modeled carbon storage potentials verified by an auditing firm. The counties may also decide to model different management and harvesting scenarios. After third-party certification of the carbon storage practices a final decision about marketing carbon credits can be made.

Recommendations

The development of this project identified several opportunities that could help strengthen carbon credit markets for forest landowners and managers in Minnesota and make market entry easier. The recommendations resulting from this project should be considered within the context of recommendations that have already been made by others, including the University of Minnesota's Terrestrial Carbon Sequestration Project and the Minnesota Climate Change Advisory Group, and existing recommendations have included support for reforestation and urban forestry, expanded use of forest biomass and the protection of existing forest carbon sinks and peatlands.

Statewide Baseline for Forestry Practices is needed
Currently, to participate in carbon markets for active forest management, Minnesota's forest landowners and managers need to establish their own baseline by providing high quality inventory and historic growth and removals data. This step could be simplified if a regulatory framework or statewide data source provided a more universal baseline for forest practices in Minnesota. Additional monitoring and data collection is needed to evaluate Minnesota's carbon stocks and the potential for increased carbon storage. An example of the type of data that is needed is the report prepared by the University of Minnesota for the Minnesota Forest Resources Council entitled "Status of Minnesota Timber Harvesting and Silvicultural Practice in 1996." An update to this report and interagency discussion of regulatory guidance for establishing baselines while maintaining current information about timber harvesting and silvicultural practices could help support greater carbon-credit market participation by Minnesota's forest owner and managers.

There are opportunities to build upon investments in forest certification
Many of Minnesota's land managers are well positioned to participate in carbon credit markets because they are already participating in third-party forest certification. Additional efforts, including expanded use of group certification, will be needed if Minnesota's family forest owners are going to be able to efficiently and effectively participate in carbon and ecosystem service markets. These efforts could include monitoring and inventory training for service providers to support systems that are compatible with carbon protocol requirements, enhancements to the Forest Stewardship Program, incentives to encourage land owner participation, and statewide guidelines for monitoring and field verification protocols.

Use of area regulation vs. volume regulation will be one determinate for identifying which protocol is the best fit for a land manager
The fact that some Minnesota land managers utilize area regulation (control) methods has significant implications for available future carbon under the existing standards. It is likely that current eligibility under the Voluntary Carbon Standard (VCS) will be more favorable for this management system. An annual allowable cut or volume regulation approach is more compatible with the CCX standard. As additional regional and/or national standards continue to develop other protocols should be evaluated.

Common components for forest inventory practices are needed to support carbon credit accounting

The CSA inventory used in the project is a stand-level inventory that provides information on cover type, stand size, stocking, composition, stand age, health and condition, and some measures of site productivity. Individual tree data from actual inventory plots was not readily available and would have been ideal to conduct the modeling exercises. To ensure that carbon stock estimates and modeling work can be done efficiently and as accurately as possible it is important that land managers maintain high quality forest inventory data and that the data include the metrics required for the carbon credit protocols and the modeling program. Land managers can still use different inventory systems to meet their goals and needs while just ensuring that the specific metrics needed for carbon credit accounting are included within their particular approach. The metrics to consider in the inventory include site index and residual basal area. Harvest prescriptions should also include target basal area. If inventory protocols address understory stocking and coarse woody debris additional carbon stock calculations can be supported.

Support for policies and behaviors that favor forest-based carbon credits.

Minnesota's forestry stakeholders have an opportunity to help inform the current international debate about credible carbon credit protocols and the inclusion of forest-based carbon offsets that include active management and long-lived wood products. Short of international agreement, there are things that could be done on a county, state or national level to effectively bring about recognition of the environmental benefits and carbon storage potentials offered by responsible forestry practices and the use of wood products. Including support for sustainable bioenergy programs and reduced fossil fuel consumption, expansion of green building programs that encourage the use of local and/or certified wood products, and government and non-governmental purchasing and procurement policies that favor the use of local and/or certified wood and paper products. Also, adoption of a uniform carbon tax applied to all carbon emissions would systematically favor all highly energy efficient products (or at least those that are fossil fuel efficient), while disfavoring products with lower energy efficiency.

Table 8a. Cass County Annual Harvest Acreage by Cover Type and Intensity Class (BAU vs. Alternate)

	2008-2018							
CSA Cover Type	**BAU High**	**Alt High**	**BAU Medium**	**Alt Med**	**BAU Low**	**Alt Low**	**BAU Total**	**Alt Total**
Ash	1	-	5	-	6	-	13	-
L Hwd	-	-	8	-	2	-	10	-
Aspen	1,859	1,730	866	806	137	107	2,861	2,642
Birch	338	325	186	179	54	52	579	555
Balsam Poplar	-	-	7	60	-	-	7	60
N Hwd	28	67	60	54	46	288	134	409
Oak	51	34	55	36	68	45	174	114
Red Oak	-	-	21	133	6	220	27	353
W Pine	-	-	-	-	2	1	2	1
R Pine	2	-	36	-	218	217	256	217
J Pine	441	199	82	37	25	12	549	248
W Spr	-	-	-	-	-	-	-	-
B Fir	5	7	40	59	2	3	46	69
B Spr	-	-	5	4	-	-	5	4
Tam	2	-	-	-	1	-	2	-
White Cedar	1	-	1	-	1	-	2	-
Other	2	0	1	0	0	0	3	-
Total	2,721	2361.7	1,327	1,304	564	940	4,671	4,672
% By Intensity	***58%***	51%	***28%***	***28%***	***12%***	***20%***		

Table 8b. Aitkin County Annual Harvest Acreage by Cover Type and Intensity Class (BAU vs. Alternate)

	2008-2018							
CSA Cover Type	**BAU High**	**Alt High**	**BAU Medium**	**Alt Med**	**BAU Low**	**Alt Low**	**BAU Total**	**Alt Total**
Ash	13	-	9	100	82	75	104	175
L Hwd	-	-	-	-	11	50	11	50
Aspen	1,110	900	-	100	22	100	1,132	1,100
Birch	112	250	28	-	6	-	146	250
N Hwd	315	200	102	100	578	750	995	1,050
Oak	-	-	56	50	360	400	416	450
W Pine	-	-	-	-	-	-	-	-
R Pine	-	-	6	-	43	150	49	150
J Pine	55	5	-	-	-	-	55	5
W Spr	37	-	-	-	53	50	90	50
B Fir	120	50	8	-	6	-	134	50
B Spr	32	50	-	-	-	-	32	50
Tam	51	100	-	-	-	-	51	100
Total	1,845	1,555	209	350	1,161	1,575	3,215	3,480
% By Intensity	***56%***	***43%***	***7%***	***10%***	***36%***	***47%***		

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