Extending Forest Rotation Age for Carbon Sequestration: A Cross-Protocol Comparison of Carbon Offsets of North American Forests

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Abstract

As the issue of climate change rises in prominence, growing attention is being paid to the ability of forests to mitigate rising atmospheric concentrations of CO_2. Through carbon offset programs, forest owners can be offered financial incentives to enhance the uptake and storage of carbon on their lands. This project presents a modeling framework within which the creditable carbon potential can be quantified from extending the rotation age of multiple forest stands. The differences in creditable carbon potential from rotation extensions across several North American forest types are explored. Additionally, the model enables the comparison of project creditable carbon amongst three accounting methodologies: the Department of Energy 1605b Registry, the Chicago Climate Exchange Protocol, and the Voluntary Carbon Standard Protocol. There are important methodological differences between these carbon accounting schemes which have implications to both forest owners and policymakers alike. It is shown here that the inclusion of methodologies to account for such issues as leakage, permanence, additionality and baseline-establishment, while increasing the overall legitimacy of any forest carbon offset program, can reduce creditable carbon to the forest owner by up to 70%. Regardless of the protocol used, Pacific Northwest forest types emerge as the most effective at sequestering carbon on a per area basis.

Introduction

One of the greatest environmental issues facing modern policymakers and citizens alike is global climate change. This change is very likely a result of rising atmospheric concentrations of anthropogenic greenhouse gases (GHGs), most notably carbon dioxide (CO_2) (IPCC, 2007). Thus, societal control and regulation of CO_2 emissions is of paramount importance in finding a way to mitigate climate change. The United States government has considered regulating CO_2 and other GHGs for decades; however this process has yet to produce any binding legislation. In the absence of national regulation, many regions of the country have endeavored to create their own GHG initiatives. The Regional Greenhouse Gas Initiative (RGGI), the Midwestern Greenhouse Gas Reduction Accord (MGGRA) and the Western Climate Initiative (WCI) are all examples of such pioneering efforts. Additionally, market forces have begun to demand that businesses mitigate their climate impact for public relations reasons, even in the absence of formal legislation. As a result, organizations and individuals alike are looking for the most efficient ways to reduce their carbon impact.

An emitter interested in reducing carbon emissions, whether the impetus is environmental, economic or legal, is presented with one of two options. First is to reduce emissions directly, either through reduced production, switching fuels or technological improvements. Option two would be to assure the existence of a carbon offset from another entity, meaning that they could validate an equivalent amount of CO_2 to their desired reduction being reduced elsewhere. These offsets could come in a number of different areas, from emissions reductions by the offsetting entity, to reduced-tillage agriculture, to increased carbon storage through improved forest management.

Forest carbon offsetting schemes have drawn particularly heavy attention in recent years, as international, national and regional markets have begun to develop for the sale of carbon credits from avoided deforestation, afforestation and improved forest management programs. In the United States in 2007, forestry and land-use activities sequestered an amount equivalent to 15% of total U.S. domestic GHG emissions, thus the potential for meaningful climate gains to be made through forestry projects is high (EPA, 2009). Additionally, many cobenefits to both ecosystems and local communities accrue from increasing the stock of forests. The incorporation of a legitimate forest offset program in climate legislation has drawn support as a cost-reduction measure, as the inclusion of carbon sinks has been shown in most cases to reduce the economic burden of overhauling the present carbon-intensive economy (van Kooten *et al.*, 2004).

When an emitter needs to obtain an offset for one unit of CO_2 they have generated,[1] they can pay a forest-owning entity to increase the amount of CO_2 being captured by their forests by an equivalent amount. This enhanced capture can be accomplished in a number of different ways, from avoiding deforestation to planting new trees (through either afforestation or reforestation) to improving forest management (IFM). There are many activities that are within the scope of IFM, such as reduced-impact logging, improved forest productivity or conversion of a logged forest to a protected forest. A final option for a forest owner looking to improve forest management for carbon sequestration benefits, and the one that will be the focus of this analysis, is the extension of the forest rotation age to capture more carbon before wood products are harvested and sent to market.

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[1] Units of CO_2 emission and sequestration are often measured in Megagrams (Mg) in the scientific literature and in metric tons or tonnes (T) in policy discussions. Both are equivalent, and equal 1.10 short or U.S., tons.

As offset markets have begun to develop in response to legislative and market pressures, forest owners have an increasing financial incentive to consider carbon sequestration as part of their management portfolio. However, the methodological legitimization of any forest offsetting scheme is not a trivial matter, and has led to a great deal of controversy in policy development (Beane *et al.*, 2008). The most important aspect of an offset program is to establish credibility in order to assure that credits generated will retain long-term value and accurately represent the amount of carbon that is actually being sequestered as a result of management changes. At the most basic level, estimations of sequestration must be well-vetted either through on-site measurement or modeling. Additionally, forest offset methodology must address the issues of project baseline, leakage and risk-buffer establishment.

In any carbon accounting program, a baseline must be established to which carbon accrual over the project lifetime can be referenced. Leakage, defined as the unanticipated change in GHG benefits outside of the project's accounting boundary as a result of project activities (IPCC, 2000), is another issue that emerges in carbon offset policy. In the case of forestry projects, leakage would refer to the reduced timber harvest resulting from a sequestration project inducing another land-owner to harvest their forest to fill the market gap, thus reducing the potential carbon benefit of the offset. Finally, the issue of permanence (i.e. – the ability of the project to ensure long-term sequestration) takes on an important role in forest offset programs. Forests are particularly susceptible to wildfire and pest disturbance, which could lead to a large unintended release of sequestered carbon from the project.

The variety of national and regional GHG initiatives including forest offsets that have emerged within the past decade has led to a wide spectrum of accounting methodologies to estimate creditable carbon.[2] This has created a confusing situation for forest owners, as they now have many different markets to ply potential forest carbon offset credits in, each with a different methodology for calculating creditable carbon. The emergence of a national methodological standard is clearly needed to simplify the forest offsetting process, and to assure long-term market viability for carbon sequestration projects. Until this time however, analyses such as the one presented in this paper are necessary to help forest owners recognize the potential benefits of carbon offset projects across a variety of different markets.

The impetus behind this analysis was threefold. First was to compare creditable carbon sequestration potential across several North American forest types. There are important differences in growth yield curves and inter-carbon pool dynamics between forests based on region and species mix. These differences lead to a large degree of variability in the rate at which forests can sequester carbon, the pools in which it is stored, and the offset potential to the forest owner. An exploration of these fundamental differences helps both forest owners and policymakers better understand how offset policy could unevenly stimulate management for sequestration across forests.

The second motivation for the research presented here was to compare major forest offset programs, in an effort to assist forest owners in initial forest stand assessment for offset potential. This study compares creditable carbon potential across three accounting methodologies:

[2] See Galik *et al.,* (2008) for a comprehensive analysis of present forest offset methodologies

1) The U.S. Department of Energy (DOE) 1605(b) Technical Guidelines for Voluntary Reporting of Greenhouse Gases[3]
2) The Chicago Climate Exchange (CCX) Sustainably Managed Forests/Long-Lived Wood Products Protocols[4]
3) The Voluntary Carbon Standard (VCS) Improved Forest Management Protocol[5]

Depending on which methodology is used, large differences in project creditable carbon can arise from the treatment of concepts such as baseline generation, risk buffer establishment and leakage. As most forest offset programs have been compiled and put into action in a relatively short time frame there has been minimal detailed analysis on the practical applications of these accounting methodologies. There has been even less work done on making comparisons across methodologies. Previous research has been largely region-specific, but has found that large differences in creditable carbon potential from forest carbon sequestration exist between accounting methodologies (Galik *et al.*, 2008; Pearson *et al.,* 2008). This study extends these previous analyses to include a spectrum of 46 forest types from across the continental United States, making possible an assessment of the relative creditable carbon potential across ecosystems.

The third objective of this analysis was to develop a simplified modeling framework for assessing the creditable carbon potential from rotation age extensions in forest ecosystems across the United States. The quantification of forest carbon in a given parcel of land is not a trivial task. On-site measurement requires a good degree of methodological knowledge, as well as time and proper equipment. For this reason, there is a basic need for modeling tools which can roughly estimate the amount of carbon in a stand for a forest owner with minimal on-site measurement. These modeling tools would

[3] More information can be found at: http://www.pi.energy.gov/enhancingGHGregistry/, accessed 3/222/09
[4] More information can be found at: http://www.chicagoclimatex.com/, accessed 3/222/09
[5] More information can be found at: http://www.v-c-s.org/afl.html, accessed 3/222/09

enable landowners to estimate whether extending rotation age would improve carbon sequestration on the scale that they desire.

There are a wide range of carbon modeling tools presently available. Some models are quite simple to use, however they can only produce analyses at the regional level.[6] The model presented in this study uses data derived from the USFS Forest Inventory Analysis (FIA) National Program. The FIA program is comprised of a network of over 300,000 sampling plots across the U.S. (USDA, 2007). With a wealth of data from across a broad spectrum of regions and forest types, the FIA summary data used here enables the modeler to produce ecosystem-specific results. There are other models available which have also been developed to be very stand-specific; however the user interface in these cases is oftentimes complex enough to deter the average forest landowner from using them.[7] This study presents a unique Microsoft Excel™-based modeling platform intended to combine stand-level quantification ability with a user-friendly interface. Additionally, this model is unique in its ability to capture inter-protocol differences in creditable carbon potential from rotation age extensions.

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[6] For example, the Carbon Online Estimator (COLE), available at http://ncasi.uml.edu/COLE/, enables the user to identify forest carbon characteristics from any region of the U.S.
[7] For example, the Forest Vegetation Simulator (FVS), available from the USFS at http://www.fs.fed.us/fmsc/fvs/, allows the user to generate stand-level carbon reports from site-specific plot-level data and a variety of timber management options.

Materials and Methods

The following sections outline the methodology used to model extensions in rotation age for carbon offset credit. The first section provides specifics on the modeling framework developed for this analysis. The second section describes how carbon data obtained from the FIA was aggregated and used in the model. Finally, a description is provided of how each of the three carbon accounting methodologies under examination was represented in the model.

Modeling Methodology

To simulate the carbon sequestration potential of extending forest rotation age, a modeling framework was constructed that tracks forest carbon accrual on an annual basis. The user begins by selecting one of 46 pre-defined forest types. Each forest type is a combination of a geographic region (Table 1), and a species mix, and as a group represent the major forest ecosystems across the continental United States. The model compares the resultant creditable carbon generated from the extension in rotation age across three carbon accounting methodologies: DOE, CCX and VCS. Within the model, forest carbon is broken down into five representative pools: live tree, standing deadwood, down deadwood, understory and forest floor. Definitions used for each pool are found in Table 2.

Age-volume data points, also known as a yield curve, for each forest type serve as the starting point for estimating stand carbon, and were taken from Appendix A of Smith *et al.,* (2006). The relationships are ecosystem-level estimations and assume an average level of planting and stand management, as determined from the underlying FIA sampling data (Smith *et al.*, 2006). While the site-specific yield curve for any individual forest would likely be slightly different, these ecosystem-level yield curves are still applicable for obtaining a rough first estimate of creditable carbon potential. As volume data points from Appendix A of Smith *et al.,* (2006) were given at only 10 year increments, the model used here generates estimates for each intermediate year using data linearization.[8]

Table 1 – Forest Regions Defined by State

Region Code	Region Name	States Included
NE	Northeast	CT, DE, MA, MD, ME, NH, NJ, NY, OH, PA, RI, WV, VT
NLS	Northern Lake States	MI, MN, WI
NPS	Northern Prairie States	IA, IL, IN, KS, MO, NB, ND, SD
PNWE	Pacific Northwest, East	OR, WA (East-side)
PNWW	Pacific Northwest, West	OR, WA (West-side)
PSW	Pacific Southwest	CA
RMN	Rocky Mountain, North	ID, MT
RMS	Rocky Mountain, South	AZ, CO, NM, NV, UT, WY
SE	South Central	AL, AR, KY, LA, MS, OK, TN, TX
SC	Southeast	FL, GA, NC, SC, VA

Table 2 – Modeled Carbon Pool Definitions (taken from Smith *et al.,* (2006))

Carbon Pool	Definition
Live Tree	Live trees with diameter at breast height (dbh) of at least 2.5 cm (1 inch), including carbon mass of coarse roots (greater than 0.2 to 0.5 cm, published distinctions between fine and coarse roots are not always clear), stems, branches, and foliage.
Standing Deadwood	Standing dead trees with dbh of at least 2.5 cm, including carbon mass of coarse roots, stems, and branches.
Understory	Live vegetation that includes the roots, stems, branches, and foliage of seedlings (trees less than 2.5 cm dbh), shrubs, and bushes.
Down Deadwood	Woody material that includes logging residue and other coarse dead wood on the ground and larger than 7.5 cm in diameter, and stumps and coarse roots of stumps.
Forest Floor	Organic material on the floor of the forest that includes fine woody debris up to 7.5 cm in diameter, tree litter, humus, and fine roots in the organic forest floor layer above mineral soil.

[8] The process of volume linearization involves simply taking the difference between two volume data points spaced 10 years apart and distributing that increase evenly across the ten year time span, thus producing annual volume increments. In the absence of a mathematical age-volume relationship, this method was determined to be adequate for roughly estimating the magnitude of changes in volume on an annual basis.

Using these yield curves, the model then estimates the ideal forester's (harvesting at the mean annual growth maximum of the forest) and Faustmann (harvesting at the net present value maximum of the forest) rotations. These rotation ages are unique to each forest type, as the yield curves of each are different. Figure 1 shows the diversity in yield curves for a range of prominent North American timber species. The model uses a discount rate of five percent in calculating net present value, which is consistent with recent literature on forest management (Galik *et al.,* 2008; Sohngen and Brown, 2006). The model user must then select either of these values for the modeled baseline rotation age. In most cases the Faustmann rotation is significantly shorter than the forester's rotation (Table 3). By definition, the Faustmann rotation accounts for the revenue from timber harvest, and thus also the marginal cost of delaying that harvest (Conrad, 1999). Incorporating this economic component often leads to a harvesting of the forest in advance of the maximum in mean annual growth.

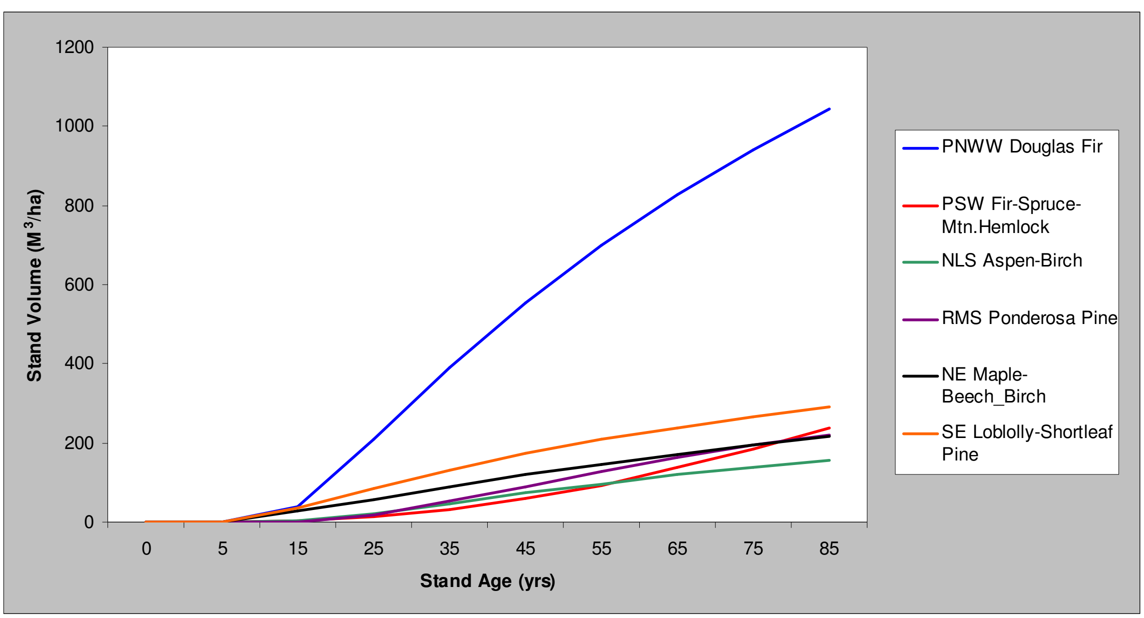

Figure 1 – Yield curves for prominent North American timber forest types from Smith *et al.,* 2006

Table 3 - Model-generated Optimal Rotation Ages for Prominent North American Forest Types		
	Forester's Rotation	**Faustmann Rotation**
SE Loblolly-Shortleaf Pine	45	26
NE Maple-Beech-Birch	55	25
PNWW Douglas Fir	65	34
NLS Aspen-Birch	75	37
RMS Ponderosa Pine	125	47
PSW Fir-Spruce-Mtn.Hemlock	125	48

The user subsequently enters the number of years by which the baseline rotation age is to be extended, the number of stand ages in the project and the area of each stand. The model then runs both the extended rotation case as well as the baseline case where applicable (VCS) through a 100 year project lifespan, calculating creditable carbon for the DOE, CCX and VCS methodologies. All reported model-generated values are in Mg CO_2e/ha/yr, and from this point on in this paper, modeled "creditable carbon" refers to these outputs. All cumulative carbon values are discounted over time. Discounting in forest carbon offsetting is necessary from both an economic and a biological perspective. As these creditable carbon estimation are being used in the end to calculate revenue over time, they should be discounted in the same manner as this revenue would be (van Kooten *et al.*, 1995; Newell and Stavins, 2000).

The analyses in this paper utilize the calculated Faustmann condition for the baseline rotation age, simulating management of the forest for maximum revenue. The baseline rotation was then extended by five years to obtain the extended rotation scenario. The magnitude of this extension was intended to mimic the decision of a forest owner looking to moderately alter their management regime. A forest owner must recognize the detriment of delaying timber revenue from too long of a rotation age extension, as well as the overhead costs of establishing a carbon accounting program which may make too short of a rotation age extension financially ineffectual.

Each of the 46 forest types in the model was run using the same five year rotation extension scenario. The baseline Faustmann rotation is of a different length for each forest type as a result of differences in productivity. As a result, it is important to note that the extension of the baseline rotation by five years represents a greater percentage increase in forests with a shorter rotation length. Thus, the rotation extension scenarios modeled in this analysis may not be equally realistic across all forest types, but were nevertheless necessary for cross-comparison.

Carbon Pool Methodology

Live Tree

In a mature forest stand, the live tree pool represents the majority of aboveground carbon, as evidenced by the example of Douglas fir (Figure 2). Ecosystem level equations that the USFS has developed from the most recent FIA data were obtained (pers. comm., J. Smith U.S. Forest Service (12/09/08)), and live tree carbon was estimated for each forest type using the formula:

$$\textit{Live Tree Carbon} = 0.5 * (a+b*\textit{Volume}^{c})$$

where carbon is in Mg/ha and volume is in M^3/ha. Live tree coefficients can be found in Appendix 1.

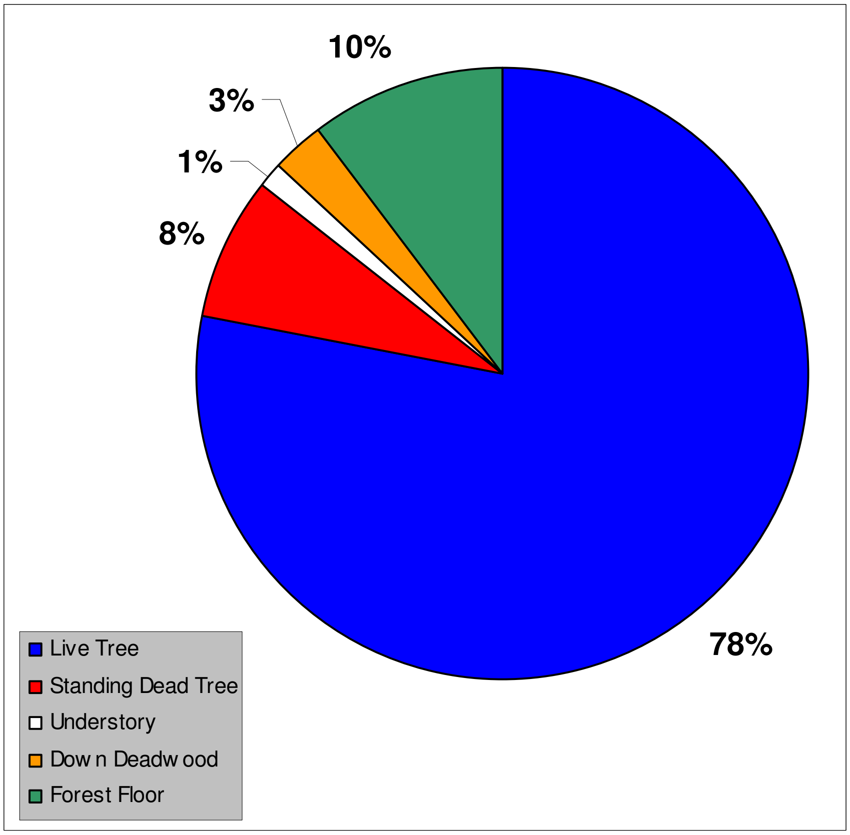

Figure 2 – Aboveground forest carbon partitioning in a PNWW Douglas fir stand at age of optimal Faustmann harvest (34 yrs)

<u>Standing Deadwood</u>

Standing deadwood pool equations were similarly generated from U.S. Forest Service FIA-based data for each forest type (pers. comm., J. Smith U.S. Forest Service (12/09/08)), and follow the formula:

$$\textit{Standing Deadwood Carbon} = 0.5 * (a * \textit{Volume}^b)$$

where carbon is in Mg/ha and volume is in M^3/ha. Standing deadwood coefficients can be found in Appendix 1.

<u>Understory</u>

The carbon in understory vegetation is generally a small portion of the total carbon in any given forest stand (U.S. EPA, 2008). Understory carbon was estimated using methodology outlined in Annex 3.12 of the EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006, from here on referred to as "Annex 3.12". Under this methodology, a ratio of understory carbon to live tree carbon was established for each forest-type using the formula:

$$Ratio = exp\^{}(a-(b*(ln\ (live\ tree\ carbon))))$$

where carbon is in Mg/ha. The forest type classifications found in Annex 3.12 were slightly different than those used in this model for some forest types. In these cases, the understory forest type that most closely described the species composition of the model forest type was used. The understory coefficients used in this analysis can be found in Appendix 2.

Down Deadwood

The biomass in a stand as down deadwood is derived from two sources: accumulation from growing trees and slash from harvesting operations. In this model, down deadwood accumulation was estimated to be a certain percentage of live tree carbon, as defined by forest-type specific ratios from Annex 3.12. The forest type classifications found in Annex 3.12 were slightly different than those used in this model for some forest types. In these cases, the down deadwood forest type that most closely described the species composition of the model forest type was used.

Modeling of down deadwood from logging slash was also forest type-specific. Initial values for logging slash as a portion of growing-stock volume at year of harvest were established using factors from Tables 5 and D-9 of Smith *et al.*, (2006). This value was subjected to an annual decay function which was also forest type specific (pers. comm., J. Smith U.S. Forest Service (3/04/09)). The slash-derived carbon was added to the carbon from accumulation to obtain a total for the down deadwood pool. The coefficients used in this analysis for generating down deadwood pool values can be found in Appendix 2.

<u>Forest Floor</u>

Forest floor carbon is one of the most dynamic pools within any forest ecosystem (Smith and Heath, 2002). It is dependent upon both a biomass accumulation rate and a detrital decay rate, both of which are ecosystem specific. Accumulation and decay rates for this analysis were taken from Smith and Heath, (2002), and are determined by the following formulas:

$$Accumulation = (a * age) / (b + age) \qquad Decay = c * exp^{-(age/d)}$$

where accumulation and decay rates are in Mg C/ha and age is the stand age in years. The forest-type classifications found in Smith and Heath (2002) were more broadly defined than those used in this model, being divided into four geographic regions and between three and six species mixes per region. For this analysis, the forest floor forest type that most closely described the region and species composition of the model forest type was used. The accumulation and decay coefficients for forest floor carbon used in this analysis can be found in Appendix 3.

<u>Mineral Soil Carbon</u>

Much has been written about the potential importance of soil from a carbon sequestration point of view, especially with regards to land-use change (Lal, 2004; Post and Kwon, 2008). However, the mineral soil carbon pool has not been included in this analysis for two reasons. First, it has been shown that the changes in soil carbon over the length of a timber management rotation on historically forested lands are relatively small

(Richter, 1999; Schlesinger and Lichter, 2001). For this analysis, it is assumed that all management decisions are being made on historically timber-productive lands. Thus from a soil carbon standpoint the effects of extending the rotation age of a forest on these lands are likely minimal. Additionally, it has been shown that there can be wide variability in soil carbon content even within a certain forest-type, based on sub-regional climate factors and individual site history (Amichev and Galbraith, 2004). Thus, as the intent of this analysis is to model changes in forest carbon at the forest-type level, it would be improper to assume any one soil carbon condition to be representative of the ecosystem as a whole.

Wood Products

The DOE, CCX and VCS accounting methodologies each give the forest manager the ability to account for the carbon sequestered in long-lived wood products generated from harvested timber. This analysis uses the 100-year methodology for wood products accounting, which gives a forest owner credit for any carbon still sequestered in in-use or landfilled wood products 100 years after harvest. The following multi-step approach was used to estimate creditable carbon in wood products:

1. Obtain the following parameters for the forest type in question (Table 4 of Smith *et al.,* (2006)):
   - Fraction of growing stock that is softwood and hardwood
   - Fraction of softwood growing stock that is sawtimber size (> 9 in dbh), and pulpwood size (5-9 in. dbh)
   - Fraction of hardwood growing stock that is sawtimber size (> 11 in dbh), and pulpwood size (5-11 in. dbh)
   - Specific gravity of hardwoods and softwoods

2. Using the timber volume at the time of harvest from Smith *et al.,* (2006) and the parameters from step one, calculate the carbon at the time of harvest in hardwood and softwood pulpwood and sawtimber respectively. Assume that the carbon content of biomass is 50%. An example calculation is shown below:

*HW sawtimber (Mg/ha) = 0.5 * Vol. (M^3/ha) * HW fraction * sawtimber fraction*

3. Obtain the percentage remaining both in use and in landfills for HW sawtimber, HW pulpwood, SW sawtimber and SW pulpwood for the geographic region in which the forest is located (Table 6 of Smith *et al.,* (2006)).

4. Calculate the creditable carbon potential from harvest by multiplying the values from steps 2 and 3, and summing the in-use and landfill components.

The 100-year wood products potential was calculated on an annual basis in this analysis, but credit was not accounted for until the year after timber harvest. After this point, the landowner receives credit for those wood products in each subsequent year. Should a forest undergo multiple rotations during a modeling period, the wood products from each harvest are added together. The wood products coefficients used in this analysis can be found in Appendices 4 and 5.

<u>Carbon Accounting Methodologies</u>

This model compares creditable carbon performance across the accounting methodologies from the DOE Carbon Registry, and CCX and VCS Carbon Protocols. Each accounting methodology is unique with respect to which carbon pools are allowed to be included in analysis (Table 4). Additionally, each protocol establishes different methodologies for accounting for project baseline and incorporating deductions for risk buffer establishment and leakage.

Table 4 – Carbon Pools Accounted for in Selected Forest Offset Protocols

	Live Tree	Standing Deadwood	Understory	Down Deadwood	Forest Floor	Wood Products
DOE	x	x	x	x	x	x
CCX	x		x			x*
VCS	x	x*	x*	x*	x*	x*

x - Denotes carbon pool is included in protocol x* - denotes optionally included carbon pool

Department of Energy 1605(b) – (DOE)

Under the Energy Policy Act of 1992, the DOE established a voluntary program to measure and record actions taken to either reduce GHGs or increase carbon storage in soil or plants (Office of Policy and International Affairs, 2006). With respect to forests, the program is only a registry intended for the reporting of carbon sequestration gains, and not a market mechanism by which those recorded gains can be bought and sold. In this point it is markedly different from the CCX and VCS protocols also examined in this analysis.

DOE establishes four on-site carbon pools and an additional wood products pool for reporting purposes. The forest manager has the option of calculating and recording carbon changes in any combination of pools for which they have data. In this analysis, all pools are included. The definitions of the four DOE on-site carbon pools as well as their corresponding pools in this analysis are listed in Table 5 (Office of Policy and International Affairs, 2007). DOE establishes a project baseline based upon the carbon in the stand at the inception of the forestry project. This is known as the "base-year" baseline methodology. All carbon that accrues in the system over the course of the project lifetime is counted as creditable carbon. DOE does not address the issues of leakage or establishing a credit buffer for catastrophic risk.

Chicago Climate Exchange (CCX)

CCX is a voluntary trading system aimed at reducing the emissions of GHGs. In the absence of a formal government-mandated cap-and-trade system for the reduction of

Table 5 – DOE Carbon Pool Definitions

Carbon Pool	Definition	Corresponding Model Pool
Trees	All above- and below-ground portions of all live and dead trees, including the merchantable stem; limbs, tops, and cull sections; stump; foliage; bark and root bark; and coarse tree roots (greater than 2 mm in diameter)	Live Tree, Standing Deadwood, Down Deadwood
Understory Vegetation	All live vegetation except that defined as live trees.	Understory
Forest Floor	All dead organic matter above the mineral soil horizons, including litter, humus, and other woody debris	Forest Floor
Soil	All organic carbon in mineral horizons to a depth of 1m, excluding coarse tree roots	Not Included
Wood Products	Products derived from the harvested wood from a forest, including fuel-wood and logs and the products derived from them such as cut timber, plywood, wood pulp, paper, etc. Includes both products in use and in disposal systems such as landfills (but which have not yet decayed, releasing carbon to the atmosphere as CO_2 and/or CH_4).	Wood Products

GHGs, CCX serves as a legally-binding and third-party verified system for trading in North American carbon credits (CCX, 2009). The promotion and verification of forest offset projects to sequester carbon has been an integral part to CCX trading since the market's inception in 2003. The CCX market in its present design expires in 2010. However, this analysis models well past that date to examine how the methodology employed by CCX compares to other accounting schemes on a long-term basis. As such, the results of this analysis should not be taken as representative of carbon credit potential in the actual CCX market, as no such market is guaranteed to exist past 2010.

Under CCX methodology, only the above-ground and below-ground living biomass carbon is required for project accounting. Carbon in long-lived wood products can be included in project accounting at the discretion of the project developer, and has been in this analysis. Above-ground biomass is defined as stem wood, stem bark, and branches, while below-ground biomass is comprised of coarse roots (CCX, 2006). In this model, above-ground and below-ground biomass is comprised of the live tree and understory model pools. CCX uses a base-year baseline methodology.

CCX requires a deduction for uncertainty when project carbon accrual is modeled instead of annually inventoried on-site. The deduction is to be the minimum of either 20% or two times the reported statistical error of the methodology used for baseline inventory (CCX, 2006). In this analysis, an uncertainty deduction of 20% was used. CCX also requires the placement of 20% of creditable carbon into a Forest Carbon Reserve Pool which makes them ineligible for market sale until the end of the end of the compliance period.[9] This pool is managed to buffer against any unanticipated loss of sequestered carbon through catastrophic events such as fire or pest emergence.

<u>Voluntary Carbon Standard (VCS)</u>

VCS presents a set of protocols through which programs that reduce GHG emissions or increase GHG sequestration can be verified for the world's carbon markets (VCS, 2007). VCS itself does not establish a functional market for carbon credits, but serves as a standardization framework for credit verification in many different carbon markets. VCS contains methodologies and technological guidelines for registering carbon credits from AFOLU (Agriculture, Forestry and Other Land Use) projects, including those specifically aimed at extending the rotation age of managed forests.

VCS establishes that projects should consider the same carbon pools covered by IPCC guidelines (VCS, 2007). The definitions of those pools as well as their corresponding pools in this analysis are listed in Table 6 (IPCC, 2006). Under VCS

[9] As the present CCX protocol expires in 2010, all unused buffer credits are scheduled to be returned to the forest owner at that point. However, in the hypothetical scenarios modeled here the reserve buffer extends until the end of the modeling window.

methodology, a project is required to include any and all pools which are expected to decrease above a *de minimis* limit of 5% of the total increase in carbon stock, and other pools are deemed optional. Additionally, long-lived wood products must be included. For the purposes of this analysis, all pools (except for the mineral soil pool) were included to account for the potential variability in land-owner discretion on optional pools.

Table 6 – VCS Carbon Pool Definitions

Carbon Pool	Definition	Corresponding Model Pool
Aboveground Biomass	All biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage.	Live Tree, Understory (Combined with Belowground)
Belowground Biomass	All biomass of live roots. Fine roots of less than (suggested) 2mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter.	Live Tree, Understory (Combined with Aboveground)
Deadwood	Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps, larger than or equal to 10 cm in diameter.	Standing Deadwood, Down Deadwood
Litter	Includes all non-living biomass with a size greater than the limit for soil organic matter (suggested 2 mm) and less than the minimum diameter chosen for dead wood (e.g. 10 cm), lying dead, in various states of decomposition above or within the mineral or organic soil.	Forest Floor
Soil	Includes organic carbon in mineral soils to a specified depth chosen by the country and applied consistently through the time series. The default for soil depth is 30 cm.	Not Included
Long-lived Wood Products	Products derived from the harvested wood from a forest, including fuelwood and logs and the products derived from them such as sawn timber, plywood, wood pulp, and paper.	Wood Products

Forest projects under VCS must also pass an additionality test (VCS, 2007). In this manner, the project must be shown to not be mandated by any existing laws, nor be accepted as common practice in the project region. Once this additionality test is passed, the forest owner must also establish a Business As Usual (BAU) baseline scenario as to what would have happened in the stand in the absence of management changes. In the model presented here, a baseline Faustmann rotation age is selected by the user, and thus serves as the BAU scenario.

VCS requires a leakage deduction to account for project management changes that may have effects on other forests outside the management area but still within the United States. A low leakage risk is estimated for projects which extend the rotation age by 1-10 years. All the rotation age extensions considered in this analysis were less than 10 years, thus a low leakage risk deduction of 10% was utilized.

VCS also requires a risk-estimated buffer to be set aside in order to protect against catastrophic forest loss. Project risk must be classified as high, medium or low (each with a corresponding numerical buffer deduction) based on an assessment of four factors: on-site fire potential, the existence of high-value timber on-site, illegal logging potential and the potential of the project to create unemployment.[10] For projects that extend rotation age, VCS deems that the only factor that could elevate the risk level above low is fire potential. Risk level is considered low when the fire return interval in the stand is greater than 50 years, low to medium when it is less than 50 years and fire prevention measures are in place, and high when it is less than 50 years and no fire prevention is in place. In this analysis, it is assumed that all managed lands have fire prevention in place.

Regional fire return interval for this analysis was determined using the USFS LANDFIRE database. Regions with a return interval greater than 50 were assessed a 10% buffer deduction, and those less than 50 were assessed a 20% buffer deduction. For example, the Northeastern United States has a fire return interval of over 100 years

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[10] For a more thorough explanation of how each of these factors can affect the risk of forestry projects, see the VCS Guidance for AFOLU projects at http://www.v-c-s.org/docs/Guidance%20for%20AFOLU%20Projects.pdf,

(Figure 3). Thus, in the calculation of creditable carbon, a 10% deduction has to be made and placed into a reserve buffer in case fire sweeps through the stand and negates a portion of the carbon sequestered over the project lifetime.

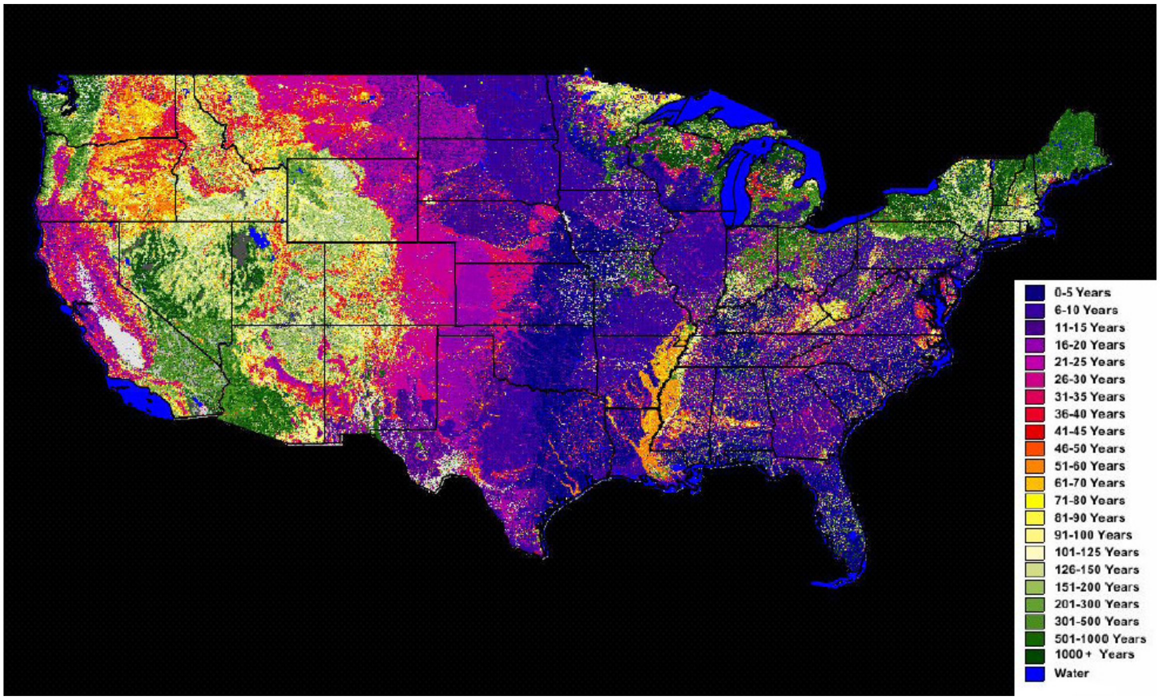

Figure 3 – Fire Return Interval for North American forests generated from the USFS LANDFIRE database (http://www.landfire.gov/)

Results

From the modeling done in this study, it is clear that the potential creditable carbon across different forest types is highly variable. Running a five year rotation extension scenario on all 46 forest types in the model, the amount of carbon generated ranges from 0.2 to 1.6 Mg CO_2e/ha/yr for DOE, 0.1 to 1.1 Mg CO_2e/ha/yr for CCX and 0.1 to 0.6 Mg CO_2e/ha/yr for VCS. Complete results for all model runs can be found in Appendix 6. Pacific Northwest forest types perform the best on a per area basis under each of the three methodologies, accruing as much as two or three times more carbon per hectare compared to forests in other geographic regions. Five of the top six performing forest types under each accounting methodology are in the Pacific Northwest (Figure 4).

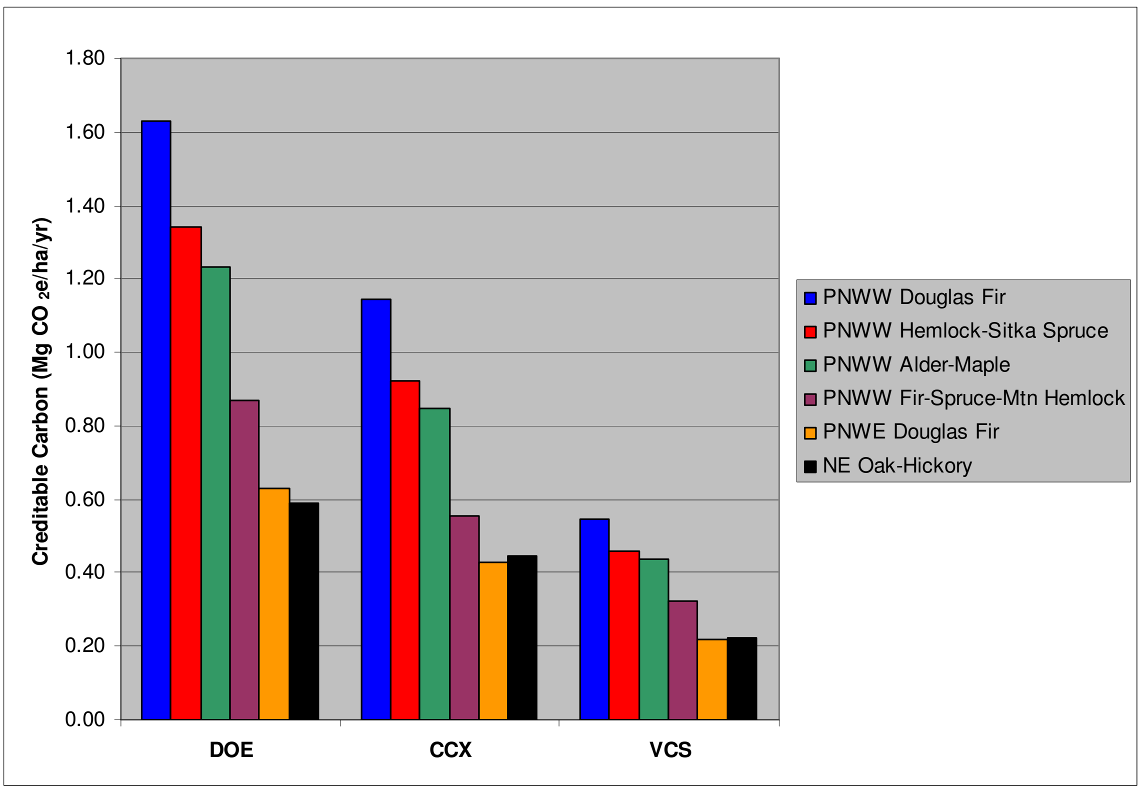

Figure 4 – Forest types generating the most creditable carbon potential from rotation length extension

Stand volume during the time of rotation age extension emerges as the primary driver of these differences in creditable carbon between forest types. A forest stand of a species mix with rapid volume growth will sequester more carbon per hectare in a year compared to one with slower volume growth. An examination of the volume tables in Smith *et al*., (2006) used for this analysis show that Pacific Northwest forest types do indeed display the highest volumes and fastest growth rates. These higher volumes enhance the carbon stock across every pool examined in the model, and lead to a higher carbon yearly increment. This in turn produces greater creditable carbon across a five-year rotation age extension.

The same species grown in different regions will not necessarily generate the same amount of creditable carbon on per area basis. Douglas fir is an excellent example of this phenomenon. As Figure 5 shows, the model-generated creditable carbon potential for Douglas fir is highly variable across the Western United States in all three accounting methodologies examined. For each methodology, a Douglas fir forest on the Western side of the Pacific Northwest is estimated to generate over five times as much creditable carbon for the same rotation age extension project than one in the Southern Rocky Mountain region.

While Pacific Northwest forests may generate the most creditable carbon to an individual landowner on a per area basis, they do not necessarily hold the greatest potential for aggregated ecosystem-level sequestration. The national acreage of each forest type must also be assessed to determine relative aggregate creditable carbon potential. Using area data from the USFS FIA database obtained through the FIDO

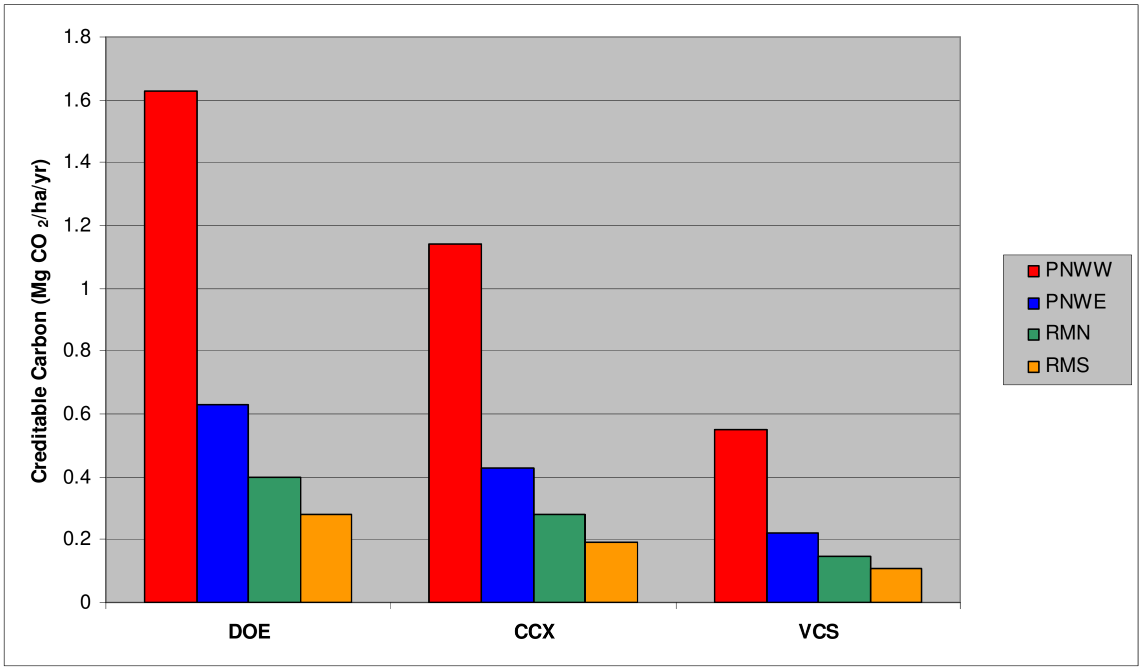

Figure 5 – Regional variation in creditable carbon potential in Douglas fir forests

(Forest Inventory Data Online) tool[11], the aggregate sequestration potential of each forest type was calculated. FIDO annual sample data covers only a subset of North American forest land, thus these calculations do not accurately represent total carbon sequestration potential. However, as the FIA sampling program is intended the provide data on a representative cross-section of North American forests, these calculations do conserve the relative performance among forest types. As Table 7 shows, the only Pacific Northwest forest in the top five with respect to aggregate carbon credit potential is PNWW Douglas fir.

Another finding of this analysis is that the addition of more regulatory complexity in forest offset policy, while intended to provide a greater deal of program legitimacy, also greatly reduces the creditable carbon accruing to a forest owner. For every forest type in the model, CCX and VCS creditable carbon were each compared to DOE to

[11] The FIDO tool is available at http://199.128.173.26/fido/index.html, data accessed on 4/7/09

Table 7 - Top Forest Types for Aggregated Creditable Carbon Potential

Forest Type	FIA Area Sampled (ha)	DOE Creditable Carbon (Mg CO_2e/ha/yr)	Total Creditable Carbon Potential of sampled area (Tg CO_2e/yr)
PNWW Douglas Fir	5,802,011	1.63	9.45
SC Oak-Hickory	24,257,977	0.30	7.20
NE Maple-Beech-Birch	16,136,146	0.42	6.78
NE Oak-Hickory	11,104,779	0.59	6.55
SC Loblolly-Shortleaf Pine	13,207,150	0.48	6.28

assess the differences between methodologies. The DOE Registry was used as the reference methodology for carbon accounting, as it includes all carbon pools and accounts for no buffer, leakage or uncertainty deductions, and the other two protocols were subsequently compared against this standard. For every forest type, creditable carbon decreased from DOE to CCX and again from CCX to VCS as deductions were made for leakage (VCS), modeling uncertainty (CCX) and risk buffer establishment (VCS and CCX). CCX methodology was estimated to generate only 60 to 80% of the creditable carbon of DOE. More strikingly, VCS generated only 29 to 52% of DOE creditable carbon. A graphical representation of the variation in creditable carbon across protocols and forest types is presented in Figure 7 for major regional timber species across the United States.[12]

The use of BAU baseline methodology in VCS also emerges as a major driver behind the reduction of creditable carbon. Figure 6 shows that across a diversity of prominent timber types, creditable carbon would more than double if VCS hypothetically employed a base-year baseline approach instead of a BAU baseline. This indicates

[12] The most prominent domestic forest types for timber were determined using the USFS FIA FIDO tool for annual removals data. For states that were not represented in the on-line data base, 2005 forest service removals data was used from Howard, (2007).

substantial policy-dependent differences in the magnitude of carbon credit potential in forests of every region.

Forest owners may be most interested in a comparison between CCX and VCS methodologies, as both represent functional protocols where carbon accounting can be immediately translated into offset payments in a carbon market. There is some degree of variability in the relative performance between these two methodologies across forest types. For each forest type, CCX generates more creditable carbon than VCS; however the VCS percent of CCX ranges from a low of 39.4% to a high of 79.5% (Table 8). Some of the variability in the relative performance of accounting methodologies across forest types can be attributed to geographic location. Three of the top five performing

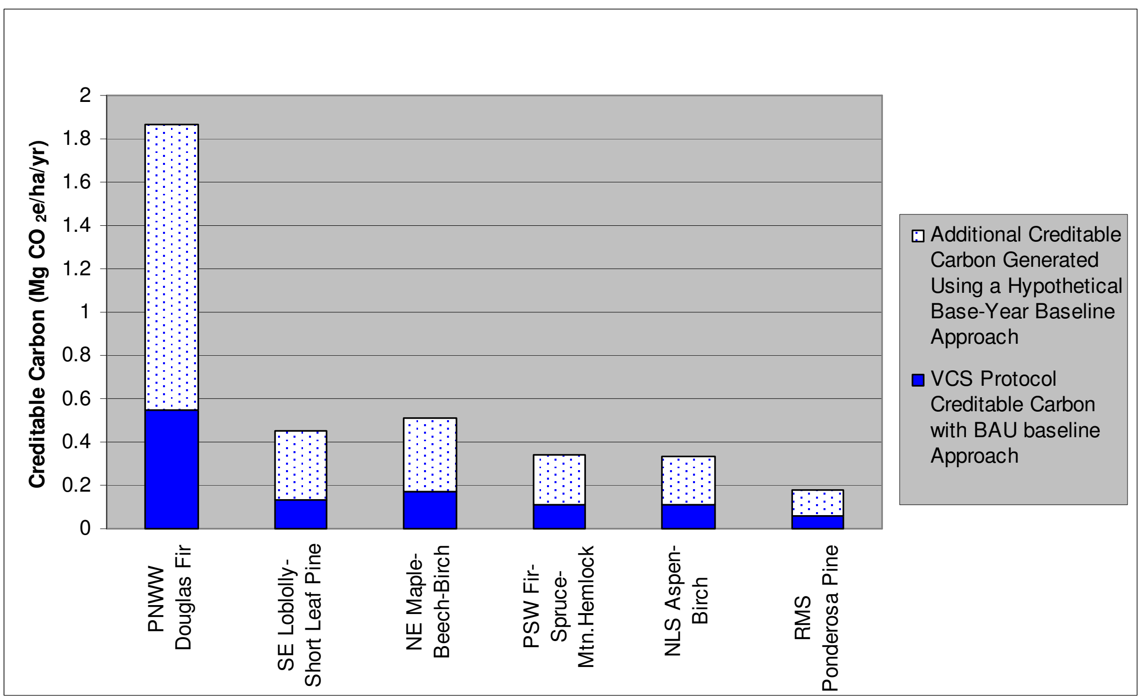

Figure 6 - The effect of VCS BAU baseline methodology on creditable carbon Potential in common North American forest types

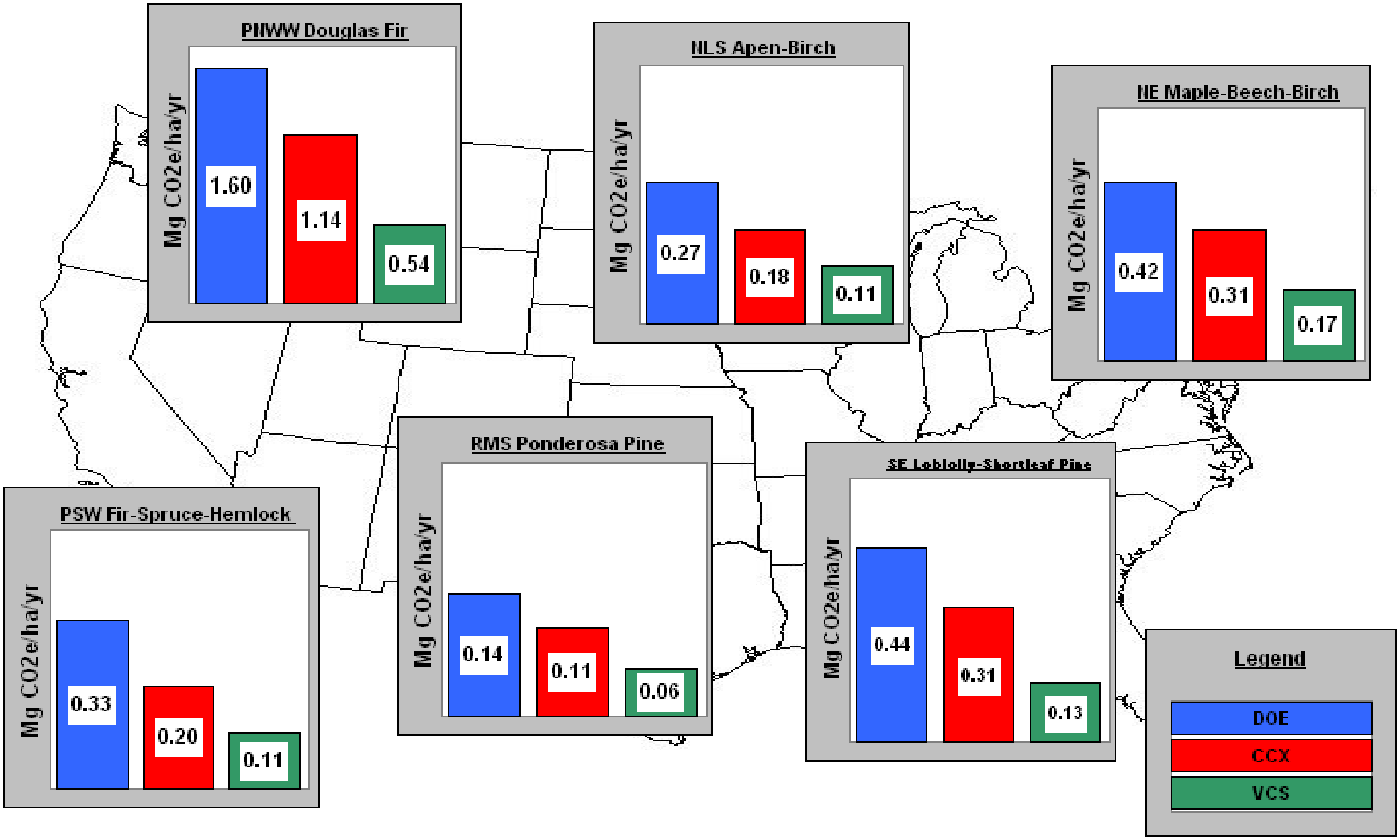

Figure 7 - Creditable Carbon generation potential from a five-year rotation length extension across a selection of North American timber species.

ecosystems for VCS with respect to CCX are in the Northern Lake States (Figure 8), while three of the bottom five are in the Southeast (Figure 9). However, a more thorough investigation of the data indicates that other forest types of either the same geographic location or same species mix do not show similar performance, indicating that other factors are at work in determining cross-protocol performance.

It is possible that the project window selected for this analysis, that is the number of years that project carbon generation is being assessed over, could be affecting the estimations of creditable carbon. As a project proceeds over time, carbon on the stand will and ebb and flow as a function of timber harvest and tree growth. As a stand ages, most forests undergo a period of slow initial growth followed by a period of more rapid growth and finally a mature asymptotic plateau. Carbon is accumulating during this whole process, but will subsequently decrease to a local minimum if the stand is harvested. The amount of carbon remaining in the stand after harvest will be highly dynamic, depending upon the on-site management practices.

The position of the forest in its harvest cycle at the end of the project window could be one of the issues driving observed differences across forest types in cross-protocol performance. Since rotation ages are necessarily variable across forest types due to differences in forest growth curves, some forest types are approaching their harvest age at the end of the project window while others have just been harvested. Any fixed time window for cross-comparison will thus be subject to this effect.

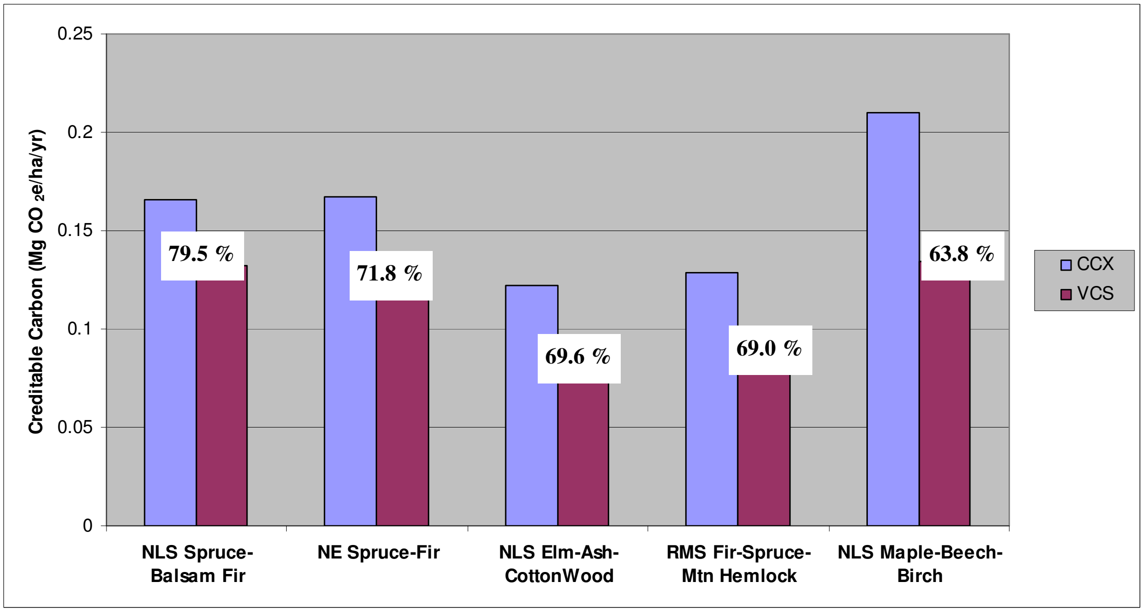

Figure 8 – Strongest performing forest types under VCS with respect to CCX

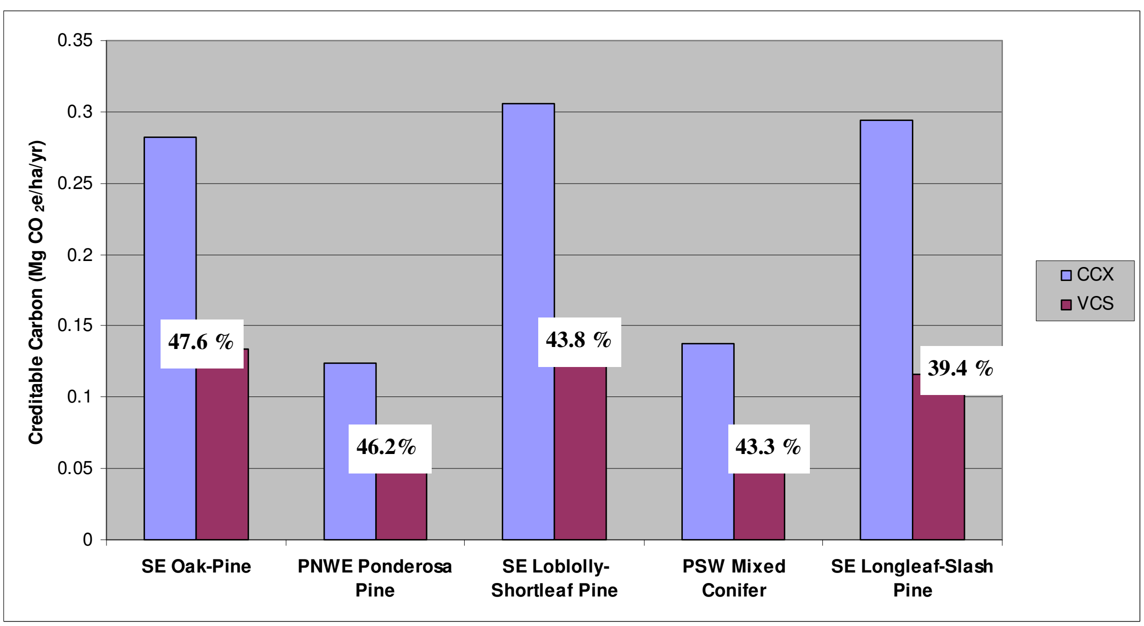

Figure 9 – Weakest performing forest types under VCS with respect to CCX

Table 8 - Strongest and Weakest Performing Forest Types in Cross-Protocol Comparison

	100-year Fixed Project Window		1-rotation Variable Project Window	
Rank	Forest Type	**VCS % of CCX**	Forest Type	**VCS % of CCX**
1	NLS Spruce-Balsam Fir	79.5%	NLS Spruce-Balsam Fir	74.4%
2	NE Spruce-Fir	71.8%	RMS Fir-Spruce-Mtn Hemlock	68.4%
3	NLS Elm-Ash-CottonWood	69.6%	NE Spruce-Fir	64.5%
4	RMS Fir-Spruce-Mtn Hemlock	69.0%	NLS Elm-Ash-CottonWood	64.1%
5	NLS Maple-Beech-Birch	63.8%	RMS Aspen-Birch	62.2%
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
42	SE Oak-Pine	47.6%	SC Oak-Pine	42.6%
43	PNWE Ponderosa Pine	46.2%	SE Longleaf-Slash Pine	40.6%
44	SE Loblolly-Shortleaf Pine	43.8%	SE Oak-Gum-Cypress	40.2%
45	PSW Mixed Conifer	43.3%	SE Oak-Hickory	39.3%
46	SE Longleaf-Slash Pine	39.4%	SE Oak-Pine	37.3%

This analysis also explored calculating creditable carbon over a variable project window of one extended rotation length instead of a fixed 100-year project window. Results were once again generated on a per year basis to facilitate cross-comparison between the variable project lengths. The two conclusions drawn from the 100-year project window analysis still hold true for the variable project window scenario. Pacific Northwest forest types with high stand volumes emerge as the ecosystems with the most creditable carbon potential on a per unit area basis (Figure 10). Additionally, DOE generates more creditable carbon than CCX in every case, as does CCX compared to VCS. Unfortunately, using a variable project window still does not adequately address the differences in cross-protocol performance between forest types. Table 8 shows that there is still regional and species variability among the forest types which perform the strongest and weakest in cross-protocol comparison.

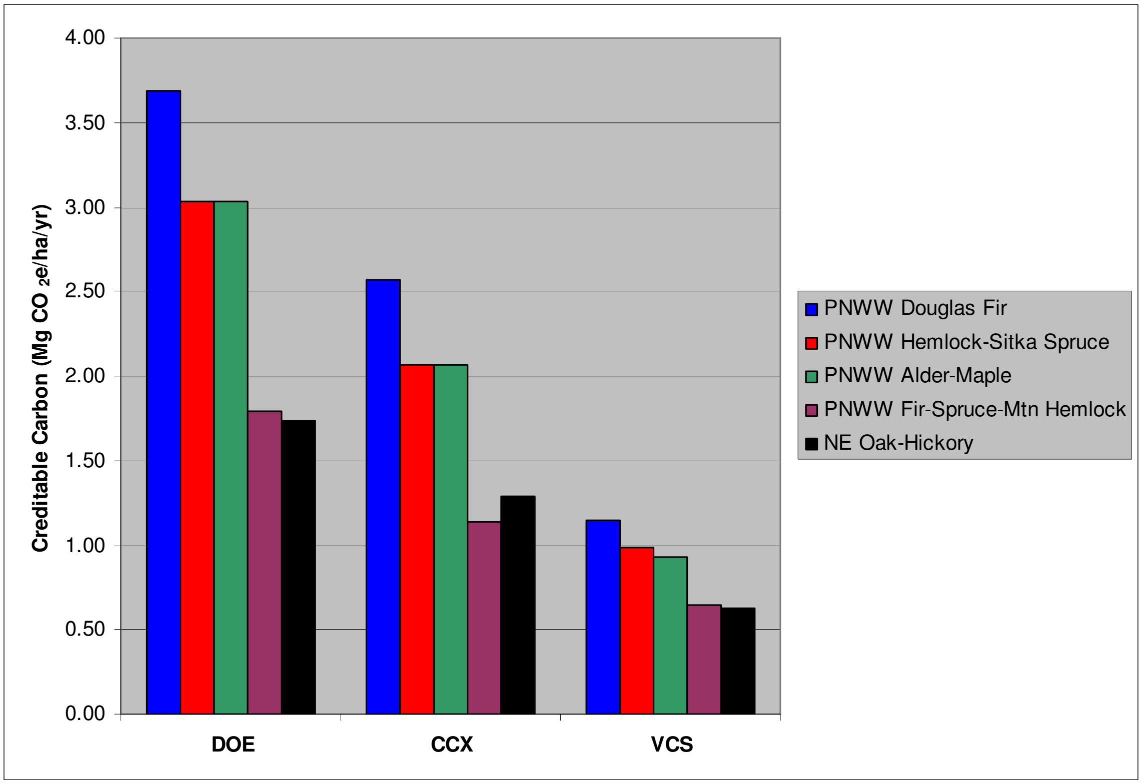

Figure 10 – Forest types generating the most creditable carbon potential from rotation length extension under a variable project window

Discussion

The analysis presented in this study has highlighted two important aspects of forest carbon offsets that have implications on forest owners and policymakers alike. First, creditable carbon potential across forest types is highly variable. Stand volume during the time of rotation age extension emerges as the primary driver for these differences in creditable carbon among forest types, and thus Pacific Northwest forests were estimated to generate the most creditable carbon on a per unit area basis. Advantageous climatic conditions for tree growth (moderate temperature and high moisture) lead Pacific Northwest forests to generally be some of the most productive and well-stocked in the country (Mills and Zhou, 2003). All other factors being equal, it then would follow that forest owners in the Pacific Northwest would be more inclined to initiate rotation age extension projects than their counterparts in other regions.

However, for the forest manager active in timber production and considering a project to extend the rotation age of their forest, there must also be a consideration of lost timber revenue. Cyclical variations in timber prices have historically played a large role in forest owner determinations of when to harvest. The extension of rotations for carbon sequestration must also take into account the effect on timber revenue and these inter-temporal variations in timber prices. The timber harvest volume will likely be greater after five years of extra growth from an extended rotation, but discounting could lead to a reduction in the net present value of that timber. While more productive forest types will generate more creditable carbon over a five year rotation age extension, the greater forgone profits from moving the timber harvest five years into the future must also be considered.

Table 9 presents a comparison of both generated carbon credit and lost timber volume for a range of common timber forest types. The data shows that those forest types which generate more creditable carbon also stand to lose more timber volume from a rotation age extension. Thus, an assessment of the most favorable forest type for carbon offsetting will depend on the relative performance of carbon accrual analyzed in this study, an assessment of regional carbon and timber prices, and predictions of future trends in those prices.

Table 9 - A comparison of Generated Creditable Carbon and Lost Timber Revenue Over 100 years from a Rotation Age Extension Project

	DOE	CCX	VCS	Timber Losses
	Mg CO_2e/ha			M^3/ha
PNWW Douglas Fir	164.6	115.5	55.2	18.2
SE Loblolly-Shortleaf Pine	44.5	30.9	13.5	6.4
NE Maple-Beech-Birch	42.4	31.2	16.8	4.5
PSW Fir-Spruce-Mtn.Hemlock	32.7	19.7	10.8	1.1
NLS Aspen-Birch	27.5	18.3	11.1	1.7
RMS Ponderosa Pine	14.8	10.4	5.8	0.6

While Pacific Northwest forests with rapid volume growth were shown in this analysis to generate the most creditable carbon on a per area basis, they do not necessarily hold the greatest aggregate carbon sequestration potential. Forest types with a combination of rapid volume growth and large acreage are those that hold the greatest sequestration potential at a national level (Table 7). It is important to identify these forest types as integral to the policy effort to promote forest carbon offsetting. As these forests hold the greatest aggregate sequestration potential, policy should be aimed at fostering the growth of management for carbon among owners of these forest types.

The second focus of this analysis was on the effects of differences in forest carbon offset accounting methodologies. It was found that the addition of more stringent methodology to account for issues of leakage, uncertainty, baseline and risk buffer establishment serves to substantially decrease the amount of creditable carbon accruing to the forest owner. Results showed a decrease in creditable carbon from DOE to CCX and again from CCX to VCS for every forest type modeled. The use of a BAU baseline methodology was shown to be particularly influential in decreasing creditable carbon to the forest owner. The inclusion of these deductions in accounting programs is necessary to give them more legitimacy and long-term viability. However, it is important to understand that making these deductions in most cases decreases the profitability of forest carbon sequestration to the landowner. The exception would be the case in which increasing methodological legitimacy in carbon accounting leads to a higher carbon price in the open market, thus compensating for the associated decrease in creditable carbon.

As presented in this analysis, the forest owner is a profit-maximizing entity presently managing for long-run timber revenue. Offset policy must create a framework in which the forest owner is stimulated to forego some timber revenue for a number of years in exchange for receiving offset payments. Forest offset policy which is by nature overly cautionary in its methodology may serve to deter the profit-minded forest owner from considering carbon sequestration as part of their management portfolio.

In order to promote the development of forest carbon offsetting, it is essential that the price of carbon be established high enough to stimulate management change. It has been shown that the amount of additional carbon sequestered from rotation age extensions would increase more than tenfold if the price of carbon were to increase from $25 to $200 per tonne (Sohngen and Brown, 2006). At present without the stimulus of national cap and trade legislation the price of carbon sits below the threshold necessary to induce management changes, and thus forest carbon offsetting has yet to gain serious traction among forest managers. It would also be prudent to promote the notion that more methodologically legitimate offsets are of a higher quality, and thus deserving of higher value. In this manner, the offset market as a whole can be legitimized while simultaneously stimulating participation. If forest owners believe that high quality offsets will translate into more carbon revenue they will naturally gravitate towards them.

One issue likely of interest to forest owners that was not readily resolved through this modeling analysis was that of accounting methodology cross-performance. While there appeared to be some elements of regional preference when comparing CCX to VCS, no straightforward correlations were able to be determined. This is an important issue from the standpoint of both the forest owner and the policymaker. As the price for carbon offsets generated under CCX and VCS are not likely to be the same, the forest owner should be concerned with the creditable carbon each generates relative to the differences in the respective offset prices. The policy-maker should be interested in this issue in an effort to avoid the generation of policy that favors one region over another.

The use of a fixed project window (such as the 100-year method used in this analysis) may not be the most appropriate method for comparing creditable carbon potential across forest types. The position of the forest in its harvest cycle at the end of the project window could be one of the issues driving observed differences across forest types in cross-protocol performance. A stand near its maximum carbon storage potential at the end of the project estimation window will appear to accrue much more carbon than one which has just been harvested and thus contains a lower level of sequestered carbon. Since rotation ages are necessarily variable across forest types due to differences in forest growth curves, some forest types are approaching their harvest age at the end of the project window while others have just been harvested.

This analysis also explored calculating creditable carbon over a variable project window of one new management rotation length, however there were still no drivers found that adequately explain the relative difference in cross-protocol performance across forest types. An additional problem arises when using the variable project window methodology, as the effects of discounting play a role in the perception of creditable carbon potential across ecosystems. Forest types with a longer rotation length will have a portion of their carbon accrual discounted more heavily (i.e. - it will be in the more distant future) and thus will be estimated to have relatively less creditable carbon potential than those forest types with a shorter rotation length. Thus, forests with a shorter optimal rotation will appear to generate more creditable carbon in comparison to longer rotations under a variable window approach versus a fixed window approach. The fact that differences in volume curves across forest types necessitate the use of different rotation ages makes the task of cross-comparison of protocols across forest types statistically difficult by any project window methodology.

From the forest owner standpoint, it is important to understand the methodological differences in offset programs in order to make the most informed decision about beginning a carbon sequestration project. The final decision to proceed with any project for a profit-maximizing forest owner comes down to a comparison of timber revenue loses versus carbon revenue gains. However, the forest owner presently has many different market options in which to register their forest for offset purposes. They are thus placed in a position of needing to educate themselves on the benefits and risks of each program, and then finding the market that will generate them the most revenue in the long-run.

This paper describes a confusing situation for forest owners trying to model their forests rotation ages to capture carbon values. There are important methodological differences between registries and protocols developed to quantify forest carbon offsets, as shown by the modeling of DOE, CCX and VCS methodologies in this analysis. Looking to the future, protocol standardization at the national level will be essential in streamlining the forest offsetting process. Addressing the issues of leakage, permanence and baseline in forest carbon offset policy is essential for offset legitimization. The creation of one standardized methodology which addresses each of these issues uniformly across all forest carbon projects would greatly simplify the process for forest owners and foster the incorporation of carbon sequestration into forest management portfolios.

Additionally, a standardized accounting program would lead to an alleviation of concerns over long-term market viability. At present, forest owners may be unsure of which market to place their carbon sequestration projects in due to an uncertainty over how long any of the programs will remain viable. Long-term investment strategies are a key component to forest management; however the climate presently surrounding carbon offsetting is not conducive to this long-term view. Methodological and market standardization would likely lead to greater participation in forest management for carbon.

Forest carbon offsetting policy is in its infancy. As a result, a great deal of modeling still needs to be done for forest owners to properly assess the economic potential of management changes in their forests to accelerate carbon sequestration. This analysis represents a first step in identifying important differences among forest types as well as among carbon offset accounting methodologies. Forest management has the potential to play a vital role in mitigating climate change, but in order to do so a legitimate and robust framework must be developed which provides incentives for land owners to participate in carbon sequestration.

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Appendix 1 - Live Tree and Standing Deadwood Coefficients for Carbon Pool Calculation					
Forest Type	Live Tree CoeffA	Live Tree CoeffB	Live Tree CoeffC	Standing Deadwood CoeffA	Standing Deadwood CoeffB
NE Aspen-Birch	26.384	2.964	0.790	1.000	0.499
NE Maple-Beech-Birch	32.572	2.804	0.823	3.041	0.306
NE Oak-Hickory	32.041	2.171	0.882	3.332	0.191
NE Oak-Pine	41.520	1.512	0.919	1.725	0.311
NE Spruce-Fir	31.715	2.271	0.829	5.893	0.190
NE White-Red-Jack Pine	37.326	2.012	0.850	2.841	0.254
NLS Aspen-Birch	24.107	2.225	0.844	1.962	0.400
NLS Elm-Ash-CottonWood	27.498	2.405	0.859	3.755	0.253
NLS Maple-Beech-Birch	22.920	2.681	0.851	3.442	0.219
NLS Oak-Hickory	38.538	2.511	0.878	2.949	0.236
NLS Spruce-Balsam Fir	17.053	2.787	0.812	1.320	0.472
NLS White-Red-Jack Pine	1.358	3.767	0.752	2.844	0.266
NPS Elm-Ash-Cottonwood	27.498	2.405	0.859	3.755	0.253
NPS Maple-Beech-Birch	22.920	2.681	0.851	3.442	0.219
NPS Oak-Hickory	38.538	2.511	0.878	2.949	0.236
NPS Oak-Pine	33.883	2.119	0.859	1.364	0.394
PNWE Douglas Fir	9.982	3.271	0.786	3.935	0.312
PNWE Fir-Spruce-Mtn Hemlock	14.031	1.832	0.855	4.550	0.358
PNWE Lodgepole Pine	10.059	2.751	0.746	1.177	0.501
PNWE Ponderosa Pine	11.925	1.597	0.871	1.000	0.455
PNWW Alder-Maple	22.715	1.000	0.951	2.190	0.466
PNWW Douglas Fir	29.866	1.204	0.942	1.237	0.559
PNWW Fir-Spruce-Mtn Hmlck	16.944	2.345	0.846	4.235	0.415
PNWW Hemlock-Sitka Spruce	30.012	1.000	0.948	1.546	0.562
PSW Fir-Spruce-Mtn Hemlock	16.944	2.345	0.846	4.235	0.415
PSW Mixed Conifer	13.551	1.899	0.874	1.000	0.608
PSW Western Oak	17.307	3.520	0.810	1.996	0.348
RMN Douglas Fir	9.982	3.271	0.786	3.935	0.312
RMN Fir-Spruce-Mtn Hemlock	14.031	1.832	0.855	4.550	0.358
RMN Lodgepole Pine	10.059	2.751	0.746	1.177	0.501
RMN Ponderosa Pine	11.925	1.597	0.871	1.000	0.455
RMS Aspen-Birch	17.787	3.353	0.764	3.062	0.376
RMS Douglas Fir	15.527	3.337	0.802	2.200	0.460
RMS Fir-Spruce-Mtn Hemlock	11.807	3.130	0.774	6.923	0.293
RMS Lodgepole Pine	11.636	2.650	0.752	1.177	0.501
RMS Ponderosa Pine	9.537	3.706	0.738	1.944	0.292
SE Loblolly-Shortleaf Pine	34.818	1.242	0.892	1.000	0.324
SE Longleaf-Slash Pine	14.913	1.000	0.933	1.000	0.184
SE Oak-Gum-Cypress	22.242	4.018	0.754	1.770	0.329
SE Oak-Hickory	28.976	3.213	0.803	2.256	0.257
SE Oak-Pine	21.645	2.626	0.811	1.000	0.351
SC Elm-Ash-Cottonwood	49.633	1.477	0.932	2.393	0.284
SC Loblolly-Shortleaf Pine	37.244	1.553	0.846	1.203	0.271
SC Oak-Gum-Cypress	22.504	5.035	0.721	4.234	0.121
SC Oak-Hickory	46.794	1.964	0.876	2.396	0.186
SC Oak-Pine	30.637	2.734	0.798	1.133	0.337

Appendix 2 - Understory and Down Deadwood Coefficients for Carbon Pool Calculation

Forest Type	Understory CoeffA	Understory CoeffB	Understory Maximum Ratio	Down Deadwood Ratio Multiplier	SW Logging Slash as %of harvest	HW Logging Slash as % of harvest	Slash Decomp. Rate
NE Aspen-Birch	0.855	1.032	2.023	0.078	0.471	0.602	12.11
NE Maple-Beech-Birch	0.892	1.079	2.076	0.071	0.471	0.602	12.11
NE Oak-Hickory	0.842	1.053	2.057	0.068	0.471	0.602	12.11
NE Oak-Pine	1.96	1.235	4.203	0.061	0.471	0.602	12.11
NE Spruce-Fir	0.825	1.121	2.14	0.092	0.471	0.602	17.88
NE White-Red-Jack Pine	1	1.116	2.098	0.055	0.471	0.602	17.88
NLS Aspen-Birch	0.777	1.018	2.023	0.081	0.384	0.441	12.11
NLS Elm-Ash-CottonWood	0.65	0.997	2.037	0.061	0.384	0.441	12.11
NLS Maple-Beech-Birch	0.863	1.12	2.129	0.076	0.384	0.441	12.11
NLS Oak-Hickory	0.965	1.091	2.072	0.077	0.384	0.441	12.11
NLS Spruce-Balsam Fir	1.656	1.318	2.136	0.087	0.384	0.441	17.88
NLS White-Red-Jack Pine	0.74	1.014	2.046	0.072	0.384	0.441	17.88
NPS Elm-Ash-Cottonwood	1.37	1.177	2.055	0.069	0.384	0.441	12.11
NPS Maple-Beech-Birch	1.126	1.201	2.13	0.063	0.384	0.441	12.11
NPS Oak-Hickory	1.139	1.138	2.072	0.068	0.384	0.441	12.11
NPS Oak-Pine	2.014	1.215	4.185	0.069	0.384	0.441	12.11
PNWE Douglas Fir	1.544	1.064	4.626	0.103	0.133	0.081	32.28
PNWE Fir-Spruce-Mtn Hmlck	1.583	1.156	4.806	0.106	0.133	0.081	32.28
PNWE Lodgepole Pine	1.79	1.257	4.823	0.093	0.133	0.081	32.28
PNWE Ponderosa Pine	1.768	1.213	4.768	0.103	0.133	0.081	32.28
PNWW Alder-Maple	2.094	1.23	4.745	0.095	0.133	0.081	12.11
PNWW Douglas Fir	1.727	1.108	4.609	0.1	0.133	0.081	32.28
PNWW Fir-Spruce-Mtn Hmlck	1.77	1.164	4.807	0.09	0.133	0.081	32.28
PNWW Hemlock-Sitka Spruce	2.081	1.218	4.693	0.099	0.133	0.081	32.28
PSW Fir-Spruce-Mtn Hemlock	1.983	1.268	4.806	0.109	0.133	0.081	32.28
PSW Mixed Conifer	4.032	1.785	4.768	0.1	0.133	0.081	32.28
PSW Western Oak	1.571	1.038	4.745	0.042	0.133	0.081	12.11
RMN Douglas Fir	2.342	1.36	4.731	0.062	0.305	0.246	43.46
RMN Fir-Spruce-Mtn Hmlck	2.129	1.315	4.749	0.1	0.305	0.246	43.46
RMN Lodgepole Pine	2.571	1.5	4.773	0.058	0.305	0.246	43.46
RMN Ponderosa Pine	2.099	1.344	4.776	0.087	0.305	0.246	43.46
RMS Aspen-Birch	1.858	1.11	4.745	0.064	0.305	0.246	18.13
RMS Douglas Fir	5.145	2.232	4.829	0.077	0.305	0.246	43.46
RMS Fir-Spruce-Mtn Hemlock	2.861	1.568	4.822	0.079	0.305	0.246	43.46
RMS Lodgepole Pine	3.305	1.737	4.797	0.098	0.305	0.246	43.46
RMS Ponderosa Pine	3.214	1.732	4.82	0.082	0.305	0.246	43.46
SE Loblolly-Shortleaf Pine	1.752	1.155	4.178	0.081	0.09	0.254	17.88
SE Longleaf-Slash Pine	1.752	1.155	4.178	0.081	0.09	0.254	17.88
SE Oak-Gum-Cypress	0.834	1.089	1.842	0.064	0.09	0.254	8.88
SE Oak-Hickory	1.903	1.191	4.182	0.059	0.09	0.254	8.88
SE Oak-Pine	1.642	1.117	4.195	0.063	0.09	0.254	8.88
SC Elm-Ash-Cottonwood	0.917	1.109	1.842	0.063	0.09	0.254	8.88
SC Loblolly-Shortleaf Pine	2.166	1.26	4.161	0.068	0.09	0.254	17.88
SC Oak-Gum-Cypress	0.917	1.109	1.842	0.063	0.09	0.254	8.88
SC Oak-Hickory	2.089	1.235	4.17	0.067	0.09	0.254	8.88
SC Oak-Pine	1.903	1.19	4.173	0.072	0.09	0.254	8.88

Appendix 3 - Forest Floor Coefficients for Carbon Pool Calculation

Forest Type	Forest Floor Base Carbon (Mg/ha)	Forest Floor Accum. CoeffA	Forest Floor Accum. CoeffB	Forest Floor Decay CoeffA	Forest Floor Decay CoeffB
NE Aspen-Birch	10.2	18.4	53.7	10.2	9.2
NE Maple-Beech-Birch	27.7	50.4	54.7	27.7	9.2
NE Oak-Hickory	8.2	24.9	134.2	8.2	9.2
NE Oak-Pine	29.7	65	79.5	29.7	8.4
NE Spruce-Fir	33.7	62.9	57.8	33.7	8.4
NE White-Red-Jack Pine	13.8	19.1	25.6	13.8	8.4
NLS Aspen-Birch	10.2	18.4	53.7	10.2	9.2
NLS Elm-Ash-CottonWood	27.7	50.4	54.7	27.7	9.2
NLS Maple-Beech-Birch	27.7	50.4	54.7	27.7	9.2
NLS Oak-Hickory	8.2	24.9	134.2	8.2	9.2
NLS Spruce-Balsam Fir	33.7	62.9	57.8	33.7	8.4
NLS White-Red-Jack Pine	13.8	19.1	25.6	13.8	8.4
NPS Elm-Ash-Cottonwood	27.7	50.4	54.7	27.7	9.2
NPS Maple-Beech-Birch	27.7	50.4	54.7	27.7	9.2
NPS Oak-Hickory	8.2	24.9	134.2	8.2	9.2
NPS Oak-Pine	29.7	65	79.5	29.7	8.4
PNWE Douglas Fir	37.2	53.6	47	37.2	24.1
PNWE Fir-Spruce-Mtn Hmlck	37.2	53.6	47	37.2	24.1
PNWE Lodgepole Pine	24.1	43.9	87.3	24.1	24.1
PNWE Ponderosa Pine	24.1	43.9	87.3	24.1	24.1
PNWW Alder-Maple	9.3	16.5	41.1	9.3	3.4
PNWW Douglas Fir	27.5	87.5	116.7	27.5	16
PNWW Fir-Spruce-Mtn Hmlck	29.5	53.9	44.3	29.5	16
PNWW Hemlock-Sitka Spruce	27.5	87.5	116.7	27.5	16
PSW Fir-Spruce-Mtn Hemlock	37.2	53.6	47	37.2	24.1
PSW Mixed Conifer	37.2	53.6	47	37.2	24.1
PSW Western Oak	31.7	50.1	62	31.7	19.8
RMN Douglas Fir	37.2	53.6	47	37.2	24.1
RMN Fir-Spruce-Mtn Hmlck	37.2	53.6	47	37.2	24.1
RMN Lodgepole Pine	24.1	43.9	87.3	24.1	24.1
RMN Ponderosa Pine	24.1	43.9	87.3	24.1	24.1
RMS Aspen-Birch	31.7	50.1	62	31.7	19.8
RMS Douglas Fir	37.2	53.6	47	37.2	24.1
RMS Fir-Spruce-Mtn Hemlock	37.2	53.6	47	37.2	24.1
RMS Lodgepole Pine	24.1	43.9	87.3	24.1	24.1
RMS Ponderosa Pine	24.1	43.9	87.3	24.1	24.1
SE Loblolly-Shortleaf Pine	12.2	20.4	27.1	12.2	3.8
SE Longleaf-Slash Pine	12.2	20.4	27.1	12.2	3.8
SE Oak-Gum-Cypress	6	15.3	61.8	6	3.2
SE Oak-Hickory	6	15.3	61.8	6	3.2
SE Oak-Pine	10.3	15.4	20.1	10.3	2.8
SC Elm-Ash-Cottonwood	6	15.3	61.8	6	3.2
SC Loblolly-Shortleaf Pine	12.2	20.4	27.1	12.2	3.8
SC Oak-Gum-Cypress	6	15.3	61.8	6	3.2
SC Oak-Hickory	6	15.3	61.8	6	3.2
SC Oak-Pine	10.3	15.4	20.1	10.3	2.8

Appendix 4 - Factors for the Calculation of Carbon Sequestration in Wood Products

Forest Type	Softwood fraction of growing-stock volume	Sawtimber (9in.+ dbh) fraction of softwood volume	Sawtimber (11in.+ dbh) fraction of hardwood volume	Specific gravity of softwoods	Specific gravity of hardwoods
NE Aspen-Birch	0.247	0.439	0.33	0.353	0.428
NE Maple-Beech-Birch	0.132	0.604	0.526	0.369	0.518
NE Oak-Hickory	0.039	0.706	0.667	0.388	0.534
NE Oak-Pine	0.511	0.777	0.545	0.371	0.516
NE Spruce-Fir	0.87	0.508	0.301	0.353	0.481
NE White-Red-Jack Pine	0.794	0.72	0.429	0.361	0.51
NLS Aspen-Birch	0.157	0.514	0.336	0.351	0.397
NLS Elm-Ash-CottonWood	0.107	0.468	0.405	0.335	0.46
NLS Maple-Beech-Birch	0.094	0.669	0.422	0.356	0.496
NLS Oak-Hickory	0.042	0.605	0.473	0.369	0.534
NLS Spruce-Balsam Fir	0.876	0.425	0.276	0.344	0.444
NLS White-Red-Jack Pine	0.902	0.646	0.296	0.389	0.473
NPS Elm-Ash-Cottonwood	0.004	0.443	0.563	0.424	0.453
NPS Maple-Beech-Birch	0.01	0.47	0.538	0.437	0.508
NPS Oak-Hickory	0.02	0.497	0.501	0.448	0.565
NPS Oak-Pine	0.463	0.605	0.314	0.451	0.566
PNWE Douglas Fir	0.989	0.896	0.494	0.429	0.391
PNWE Fir-Spruce-Mtn Hmlck	0.994	0.864	0.605	0.37	0.361
PNWE Lodgepole Pine	0.992	0.642	0.537	0.38	0.345
PNWE Ponderosa Pine	0.996	0.906	0.254	0.385	0.513
PNWW Alder-Maple	0.365	0.895	0.635	0.402	0.385
PNWW Douglas Fir	0.959	0.914	0.415	0.44	0.426
PNWW Fir-Spruce-Mtn Hmlck	0.992	0.905	0.296	0.399	0.417
PNWW Hemlock-Sitka Spruce	0.956	0.909	0.628	0.405	0.38
PSW Fir-Spruce-Mtn Hemlock	1	0.946	0	0.372	0.51
PSW Mixed Conifer	0.943	0.924	0.252	0.394	0.521
PSW Western Oak	0.419	0.899	0.206	0.416	0.59
RMN Douglas Fir	0.993	0.785	0.353	0.428	0.37
RMN Fir-Spruce-Mtn Hmlck	0.999	0.753	0	0.355	0.457
RMN Lodgepole Pine	0.999	0.54	0.219	0.383	0.391
RMN Ponderosa Pine	0.999	0.816	0	0.391	0.374
RMS Aspen-Birch	0.297	0.766	0.349	0.355	0.35
RMS Douglas Fir	0.962	0.758	0.23	0.431	0.35
RMS Fir-Spruce-Mtn Hemlock	0.958	0.77	0.367	0.342	0.35
RMS Lodgepole Pine	0.981	0.607	0.121	0.377	0.35
RMS Ponderosa Pine	0.993	0.773	0.071	0.383	0.386
SE Loblolly-Shortleaf Pine	0.889	0.556	0.326	0.469	0.494
SE Longleaf-Slash Pine	0.963	0.557	0.209	0.536	0.503
SE Oak-Gum-Cypress	0.184	0.789	0.5	0.441	0.484
SE Oak-Hickory	0.07	0.721	0.551	0.438	0.524
SE Oak-Pine	0.508	0.746	0.425	0.462	0.516
SC Elm-Ash-Cottonwood	0.044	0.787	0.532	0.427	0.494
SC Loblolly-Shortleaf Pine	0.88	0.653	0.358	0.47	0.516
SC Oak-Gum-Cypress	0.179	0.83	0.589	0.44	0.513
SC Oak-Hickory	0.057	0.706	0.534	0.451	0.544
SC Oak-Pine	0.512	0.767	0.432	0.467	0.537

Appendix 5 - End-use Disposition Factors for the Calculation of Carbon Sequestration in Wood Products

Forest Type	%SW SawLog in use after 100 yrs	%SW SawLog in landfill after 100 yrs	%SW Pulpwood in use after 100 yrs	%SW Pulpwood in landfill after 100 yrs	%HW SawLog in use after 100 yrs	%HW SawLog in landfill after 100 yrs	%HW Pulpwood in use after 100 yrs	%HW Pulpwood in landfill after 100 yrs
NE Aspen-Birch	0.095	0.223	0.006	0.084	0.035	0.281	0.103	0.158
NE Maple-Beech-Birch	0.095	0.223	0.006	0.084	0.035	0.281	0.103	0.158
NE Oak-Hickory	0.095	0.223	0.006	0.084	0.035	0.281	0.103	0.158
NE Oak-Pine	0.095	0.223	0.006	0.084	0.035	0.281	0.103	0.158
NE Spruce-Fir	0.095	0.223	0.006	0.084	0.035	0.281	0.103	0.158
NE White-Red-Jack Pine	0.095	0.223	0.006	0.084	0.035	0.281	0.103	0.158
NLS Aspen-Birch	0.096	0.25	0.008	0.084	0.032	0.265	0.127	0.177
NLS Elm-Ash-CottonWood	0.096	0.25	0.008	0.084	0.032	0.265	0.127	0.177
NLS Maple-Beech-Birch	0.096	0.25	0.008	0.084	0.032	0.265	0.127	0.177
NLS Oak-Hickory	0.096	0.25	0.008	0.084	0.032	0.265	0.127	0.177
NLS Spruce-Balsam Fir	0.096	0.25	0.008	0.084	0.032	0.265	0.127	0.177
NLS White-Red-Jack Pine	0.096	0.25	0.008	0.084	0.032	0.265	0.127	0.177
NPS Elm-Ash-Cottonwood	0.096	0.25	0.008	0.084	0.032	0.265	0.127	0.177
NPS Maple-Beech-Birch	0.096	0.25	0.008	0.084	0.032	0.265	0.127	0.177
NPS Oak-Hickory	0.096	0.25	0.008	0.084	0.032	0.265	0.127	0.177
NPS Oak-Pine	0.096	0.25	0.008	0.084	0.032	0.265	0.127	0.177
PNWE Douglas Fir	0.116	0.221	0.116	0.221	0.046	0.219	0.046	0.219
PNWE Fir-Spruce-Mtn Hmlck	0.116	0.221	0.116	0.221	0.046	0.219	0.046	0.219
PNWE Lodgepole Pine	0.116	0.221	0.116	0.221	0.046	0.219	0.046	0.219
PNWE Ponderosa Pine	0.116	0.221	0.116	0.221	0.046	0.219	0.046	0.219
PNWW Alder-Maple	0.13	0.279	0	0.076	0.046	0.219	0.046	0.219
PNWW Douglas Fir	0.13	0.279	0	0.076	0.03	0.177	0.03	0.177
PNWW Fir-Spruce-Mtn Hmlck	0.13	0.279	0	0.076	0.03	0.177	0.03	0.177
PNWW Hemlock-Sitka Spruce	0.13	0.279	0	0.076	0.03	0.177	0.03	0.177
PSW Fir-Spruce-Mtn Hmlck	0.112	0.243	0.112	0.243	0.046	0.219	0.046	0.219
PSW Mixed Conifer	0.112	0.243	0.112	0.243	0.046	0.219	0.046	0.219
PSW Western Oak	0.112	0.243	0.112	0.243	0.046	0.219	0.046	0.219
RMN Douglas Fir	0.112	0.255	0.112	0.255	0.046	0.219	0.046	0.219
RMN Fir-Spruce-Mtn Hemlock	0.112	0.255	0.112	0.255	0.046	0.219	0.046	0.219
RMN Lodgepole Pine	0.112	0.255	0.112	0.255	0.046	0.219	0.046	0.219
RMN Ponderosa Pine	0.112	0.255	0.112	0.255	0.046	0.219	0.046	0.219
RMS Aspen-Birch	0.112	0.255	0.112	0.255	0.046	0.219	0.046	0.219
RMS Douglas Fir	0.112	0.255	0.112	0.255	0.046	0.219	0.046	0.219
RMS Fir-Spruce-Mtn Hemlock	0.112	0.255	0.112	0.255	0.046	0.219	0.046	0.219
RMS Lodgepole Pine	0.112	0.255	0.112	0.255	0.046	0.219	0.046	0.219
RMS Ponderosa Pine	0.112	0.255	0.112	0.255	0.046	0.219	0.046	0.219
SE Loblolly-Shortleaf Pine	0.104	0.232	0.036	0.105	0.037	0.267	0.063	0.125
SE Longleaf-Slash Pine	0.104	0.232	0.036	0.105	0.037	0.267	0.063	0.125
SE Oak-Gum-Cypress	0.104	0.232	0.036	0.105	0.037	0.267	0.063	0.125
SE Oak-Hickory	0.104	0.232	0.036	0.105	0.037	0.267	0.063	0.125
SE Oak-Pine	0.104	0.232	0.036	0.105	0.037	0.267	0.063	0.125
SC Elm-Ash-Cottonwood	0.11	0.224	0.048	0.114	0.034	0.251	0.056	0.12
SC Loblolly-Shortleaf Pine	0.11	0.224	0.048	0.114	0.034	0.251	0.056	0.12
SC Oak-Gum-Cypress	0.11	0.224	0.048	0.114	0.034	0.251	0.056	0.12
SC Oak-Hickory	0.11	0.224	0.048	0.114	0.034	0.251	0.056	0.12
SC Oak-Pine	0.11	0.224	0.048	0.114	0.034	0.251	0.056	0.12

Appendix 6 – Results of Model Generated Creditable Carbon Potential

Forest Type	DOE Creditable Carbon (Mg CO_2e/ha/yr)	CCX Creditable Carbon (Mg CO_2e/ha/yr)	VCS Creditable Carbon (Mg CO_2e/ha/yr)
NE Aspen-Birch	0.29	0.20	0.12
NE Maple-Beech-Birch	0.42	0.31	0.17
NE Oak-Hickory	0.59	0.45	0.22
NE Oak-Pine	0.36	0.29	0.15
NE Spruce-Fir	0.25	0.17	0.12
NE White-Red-Jack Pine	0.33	0.23	0.14
NLS Aspen-Birch	0.27	0.18	0.11
NLS Elm-Ash-CottonWood	0.18	0.12	0.08
NLS Maple-Beech-Birch	0.30	0.21	0.13
NLS Oak-Hickory	0.33	0.22	0.13
NLS Spruce-Balsam Fir	0.26	0.17	0.13
NLS White-Red-Jack Pine	0.47	0.32	0.19
NPS Elm-Ash-Cottonwood	0.29	0.19	0.10
NPS Maple-Beech-Birch	0.21	0.14	0.08
NPS Oak-Hickory	0.25	0.17	0.09
NPS Oak-Pine	0.30	0.22	0.12
PNWE Douglas Fir	0.63	0.43	0.22
PNWE Fir-Spruce-Mtn Hemlock	0.36	0.23	0.12
PNWE Lodgepole Pine	0.30	0.21	0.10
PNWE Ponderosa Pine	0.17	0.12	0.06
PNWW Alder-Maple	1.23	0.85	0.44
PNWW Douglas Fir	1.63	1.14	0.55
PNWW Fir-Spruce-Mtn Hemlock	0.87	0.55	0.32
PNWW Hemlock-Sitka Spruce	1.34	0.92	0.46
PSW Fir-Spruce-Mtn Hemlock	0.32	0.20	0.11
PSW Mixed Conifer	0.21	0.14	0.06
PSW Western Oak	0.47	0.33	0.16
RMN Douglas Fir	0.40	0.28	0.15
RMN Fir-Spruce-Mtn Hemlock	0.40	0.26	0.15
RMN Lodgepole Pine	0.29	0.20	0.10
RMN Ponderosa Pine	0.27	0.19	0.10
RMS Aspen-Birch	0.23	0.15	0.09
RMS Douglas Fir	0.28	0.19	0.11
RMS Fir-Spruce-Mtn Hemlock	0.21	0.13	0.09
RMS Lodgepole Pine	0.15	0.10	0.05
RMS Ponderosa Pine	0.15	0.10	0.06
SC Elm-Ash-Cottonwood	0.30	0.22	0.11
SC Loblolly-Shortleaf Pine	0.48	0.34	0.17
SC Oak-Gum-Cypress	0.29	0.21	0.11
SC Oak-Hickory	0.30	0.22	0.11
SC Oak-Pine	0.36	0.27	0.13
SE Loblolly-Shortleaf Pine	0.44	0.31	0.13
SE Longleaf-Slash Pine	0.41	0.29	0.12
SE Oak-Gum-Cypress	0.38	0.25	0.13
SE Oak-Hickory	0.40	0.27	0.14
SE Oak-Pine	0.40	0.28	0.13