A COST-EFFECTIVENESS ANALYSIS OF MANAGING SMALL FORESTLAND FOR CARBON CREDITS AND TIMBER.

by

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ABSTRACT

A COST-EFFECTIVENESS ANALYSIS OF MANAGING SMALL FORESTLAND FOR CARBON CREDITS AND TIMBER.

Laysa Rodrigues

Western Washington forests are amongst the most productive in the world storing high contents of carbon. Small private forest owners hold about 4 million acres of these productive forests playing a significant role in expanding carbon sequestration strategies. These landowners could participate in carbon markets if they manage their stands to store more carbon. However, their participation can be limited by high transaction costs and low carbon prices. This thesis estimated carbon credits and timber revenue within different management strategies that thinned, clear-cut and did not harvest. The revenue was compared throughout the 100 year contract period required by CCAR and NW Neutral® using a cost-effective analysis. Results were reported in nominal values and discounted values, which made a significant difference. The traditional strategy of clear cutting on 40 years rotation is still the most profitable, unless carbon prices are over $100. Transaction costs of CCAR and NW Neutral ® did not prevent forest owners from profiting when credits cost a minimum of $5, but revenue was very low.

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

Meeting the challenge of global warming will require innovation in both natural resources management and business strategy. This thesis explores the intricate ties between alternative forest management and the options small landowners must consider to participate in emerging carbon credit markets. Carbon markets represent a potential alternative income stream that may match the management objectives of many small private land owners in Washington State.

Climate change is a phenomenon caused by the accumulation of greenhouse gasses (GHG) in the atmosphere emitted by anthropogenic activities (IPCC, 2007). Increases in population, industrialization, consumption and urbanization are keys to the rising emissions. The current level of carbon dioxide (CO2) and equivalent gases in the atmosphere is 380 million tons (IPCC, 2007). GHG are particles able to trap solar rays (heat) that bounce back to the atmosphere after hitting Earth's surface. GHG trap the heat that otherwise would escape the atmosphere. Climate change has been proven to affect the biosphere in many ways, some of which may be irreversible (Bloom, 2010). The Earth's most unbalancing source of CO2 emissions comes from the anthropogenic use of fossil fuels. Deforestation and decay of biomass come in second being responsible for 17.3% of emissions (IPCC, 2007).

Citizens and governments are aware of the possible negative impacts climate change can cause, and have been trying to cut back their emissions, or invest in offset projects that sequester or avoid emissions of GHGs. For this reason, since 1990, many countries and municipalities have signed the Kyoto Protocol, while others are participating in volunteer markets or regional obligatory trading schemes. Emission trading schemes have motivated landowners to develop offset projects using their land. Forestry offsets can play a significant role in these markets because forests store significant amounts of carbon.

The plants and soil on Earth contain more than 3 times the carbon (C) than what is currently in the atmosphere. About half of this carbon is stored in forest ecosystems (IPCC, 2007). When climate change issue is in the spotlight, forests are seen more and more as part of the solution to slow down the fast pace of rising temperatures. Forest ecosystems can reduce net C by sequestering CO2, or increase net C through deforestation and natural disturbances. For this reason, sustainable management and deforestation reduction have been the focus of many studies and strategies.

Carbon trading schemes have also included forests in their protocols as to avoid emissions from deforestation and as carbon sinks. The intention of forestry offset projects is to reward landowners who change their land management in order to sequester additional carbon. However, the income generated from the sale of carbon credits vary considerably according to protocols (Pearson et al., 2008, Galik et al., 2009). Moreover, it may not be profitable for small landowners to join carbon markets due to high transaction and participation costs (Galik et al., 2009).

High transaction costs can prevent small forest owners to participate in carbon markets, which could decrease carbon sequestration. This is particularly significant for the state of Washington where 4 million forested hectares are divided into small parcels belonging to different owners. Western Washington forests are highly productive and great carbon sinks. Thus, if western Washington small landowners willing to participate in carbon markets are left out because of high transaction costs, it may represent a structural problem in these markets' protocols.

This thesis examines the costs for small forest owners to get credits for forestry projects under the California Climate Action Registry (CCAR) protocol and NW Neutral®, and compares income opportunities from different management strategies. These markets are significantly different and are accessible to Washington's forestland owners. Costs will be estimated as an independent project, rather than aggregated. Revenue will be compared for 5 different forest management options: (1) unmanaged forest with natural forest dynamics and no timber harvest, (2) thinning of 10% of the basal area from below in 40 years cycle, (3) thinning of 20% of the basal area from below in 40 years cycle, (4) harvesting surplus carbon when the stand is enrolled with NW Neutral ®, and (5) clear-cut harvest with a rotation of 40 years. Through a cost effectiveness analysis, this research will answer if participating in these carbon markets is viable for small landowners, and which is the best management option to generate the most revenue.

The following section presents a contextual background for the understanding of this research. It will be divided in six topics: forest ecosystems and carbon, Washington State forests, Washington's small forestland owners, carbon markets, forest management and transaction costs.

2. CONTEXT

2.1 Forest ecosystems and carbon

Forest ecosystems sequester CO2 from the atmosphere, but also partially respire it back. Plants absorb CO2 and light through their leaves (stomata) transforming it into energy through a process named photosynthesis. The energy and carbohydrates are used by plants to maintain vital functions and growth by allocating C to their below and aboveground biomass. Forests accumulate biomass in stems, roots, leaves, understory vegetation and organic matter in soil. Photosynthesis only happens under ideal conditions of temperature, light, moisture and ambient CO2. Photosynthesis is the only process that brings C into the system, but soils can also gain C overtime from dead plant materials that accumulate on the top soil (Harmon, 2009). On the other hand, forests lose C through plant respiration, decomposers, consumers, combustion erosion and leaching. Forests can also emit methane when organic matter accumulates on the soil (Goodall, 2005). They can be compared to a leaking bucket: there is only one way it can be filled, but has many leaking holes (Harmon, 2009). Depending on the inflow and outflow the bucket can remain full, attributing the role of carbon sinkers to forests. American forests offset 10% to 12% of all annual U.S. GHG emissions from fossil fuels (Woodbury et al. 2007).

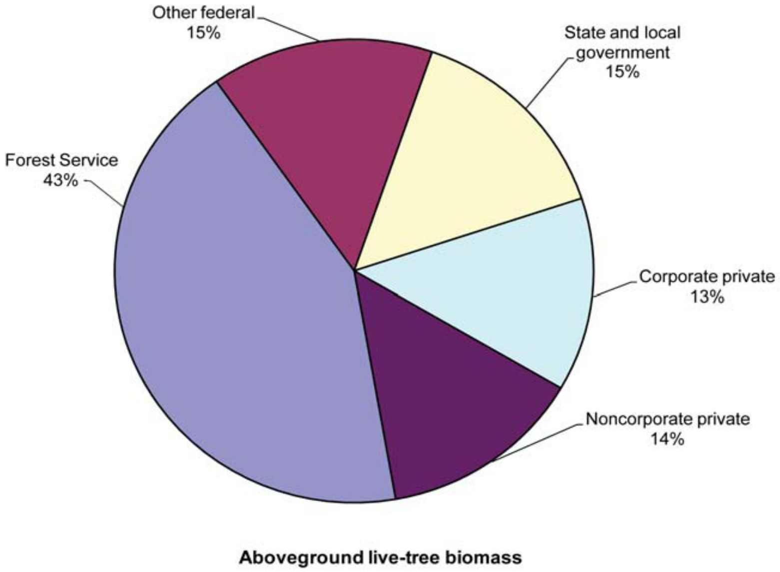
Carbon gain over the years is measured by assessing net ecosystem production (NEP), which is the increase of tree biomass, woody debris on the forest floor, and carbon in the soil minus soil and plant respiration, and decomposition. In other words, NEP is the subtraction of net primary production (NPP) from heterotrophic respiration. However, to estimate C stored in forests, the focus is on numbering the NEP. Accurate measurements of NEP are not yet possible, but there are many available tools and equations that provide close estimates.

2.2 Washington State forests

Washington forests' characteristics can be found in the US Forest Service (USFS) Forest Inventory and Analysis (FIA) Program (Campbel et al., 2010). According to the most recent report, Washington State (WA) territory encompasses 17 million hectares, of which approximately 9 million are forested covering 52.6% of the state. Climatic discrepancies differentiate WA forests into coastal, western and eastern. The Cascades mountain range prevents low clouds that come from the Pacific Ocean from moving into the eastern part of the state causing it to be dry. At the same time the range holds the clouds on the western portion causing the mild and rainy climate. Because of this, on the east side of the Cascades ponderosa pine is the dominant tree, while Douglas-fir dominates on the western side. Douglas-fir has adapted to the western climate, and it is also the most planted tree in the region, not only because of its natural characteristics, but due to its commercial features. Hemlock and Sitka spruce prevail on coastal areas because of the high humidity and fog, while fir, spruce and mountain hemlock are found on higher elevations. In general, conifers make up 86% of the WA's forests. Most of the forests in WA (about 7.3 million hectares) are classified as timberland, which is forest land capable of producing more than 1.3 cubic meter of wood per hectare a year and not legally restricted from harvest (Campbel et al., 2010). The rain forests west of the Cascades in the Pacific Northwest are rated among the most productive in the world (Andersson, 2005) making WA forests some of the greatest carbon sinks in the US.

Total estimated biomass in live trees and dead wood across Washington is 2.5 billion metric tons. Softwood stores more carbon than hardwood in WA when individually compared (Campbel et al., 2010). The aboveground live-tree biomass divided by landowner type results as depicted in the chart:

Figure 1: Total aboveground biomass stored in live trees in Washington forests divided by ownership



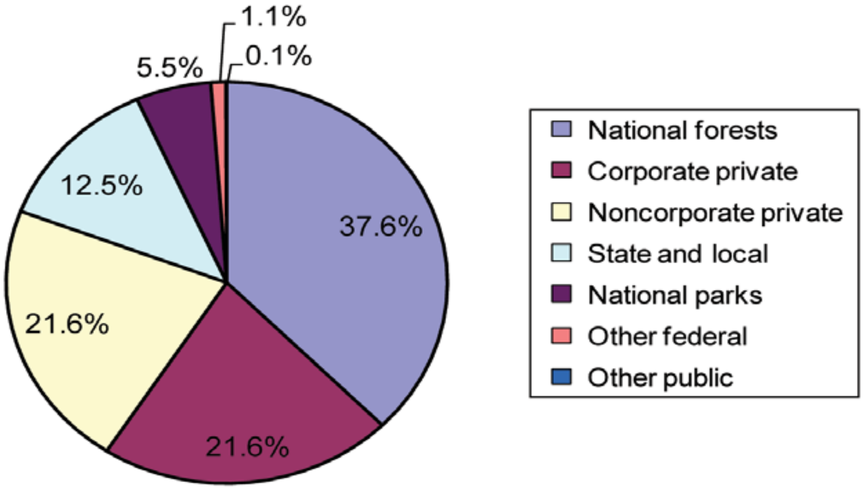
Note. This chart was adapted from Campbel et al., 2010

WA's small landowners and tribes hold 14% of the aboveground live-tree biomass in the state making them a significant group that could potentially increase C storage, and impact national net C. Carbon markets could influence this portion of landowners to increase their lands' C sequestration, if well funded.

2.3 Washington State small forestland owners

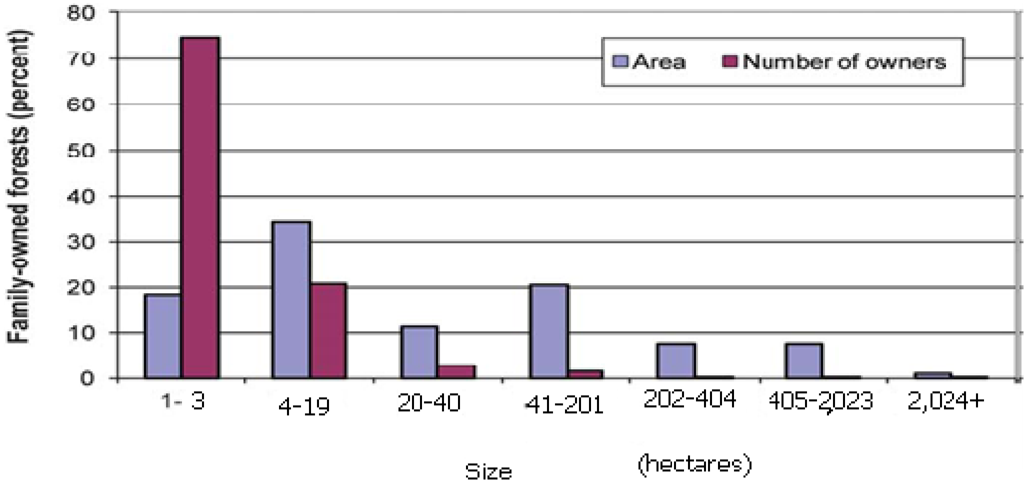
Non-industrial private forestland owners such as families, individuals, conservation organizations and Native American tribes own a significant amount of land throughout WA. Together they hold approximately 4 million hectares of forestland representing 21.6% of the total forested land (Campbel et al., 2010).Subtracting Native American tribal lands, this forested area is divided into approximately 45,000 decentralized ownerships (Hagan, 2002). Ninety-nine per cent of family owners surveyed between 2002 and 2006 by Campbel et al. (2010) own parcels of 2,024 or fewer hectares (Figure 3). Families that own 20 hectares and more can be good targets for participating in carbon markets because they are fewer and hold almost 50% of this family owned forested area. Moreover, high productivity lands are concentrated in private lands (industrial and non-industrial) making management on these lands even more significant to global net C. Forested properties have gotten smaller in the last decades (Campbel et al., 2010), which will make more difficult the participation in carbon markets (Galik et al., 2009).

Figure 2: Percentage of forest land area in Washington, by owner group, 2002–2006.



Note. This chart was adapted from Campbel et al., 2010

Figure 3: Number of family owned forests distributed by property size in hectares.



Note. This chart was adapted from Campbel et al., 2010

Many researchers have intended to formulate a non-industrial private forest owners' profile, but they have all came up with different numbers. Over 70% of these forestland owners use the land as their primary residence (Campbel et al., 2010), while for Blatner et al. (2000) only 50% do so. This may be possible because the latter did not include Native American tribal lands in the research. Non-industrial owners have an average age of about 57 years (Butler et al., 2005; Lawrance, 1992; and Campbel et al., 2010), suggesting that these lands will change ownership or be passed to other generations in the next 20 to 40 years (Campbel et al., 2010), which can be concerning in a sense that the future generation may not continue the parents' management selling the land for development realsing all the carbon stored in the forest.

Small private landowners (1 to 2,000 hectares) have different management plans and ideas about the land. According to Blatner et al (2000) survey, about half of the interviewed forest owners strongly disagreed that their forest must provide an income to cover the land expenses. Most of them (70%) also expressed concern for the land, understanding the connections of their land to a bigger ecosystem (Blatner et al., 2000), and having interest in conservation (Lawrance, 1992). However, their actions contradicted their written opinion. Timber was most harvested on their land in the 1990s when timber prices were high and they feared severe harvesting restrictions (Hagan, 2002). In Lawrance's research (1992) 65.9% of Western WA owners claimed timber as being an important source of income on their land, while 20.2% indicated special forest products, and 57% of WA's forest owners were considered to practice agroforestry (defined by Lawrance as sustainable practices aiming for constant and long term income). From the owners who apply agroforestry, 75% indicated that they do so to accomplish conservation and production goals, which would fit within carbon market requirements. Only about 13% of the family owners surveyed by Campbel et al. (2010) had written management plans, 3% participate in green certificate programs, and 3% to 8% planned to sell, subdivide, or convert their forests. Land use laws, market opportunities and tax incentives will influence the rate of forest conversion.

2.4 Carbon markets

Carbon markets encourage the maintenance of carbon stores on the landscape to slow climate change. They intend to attribute an economic value on GHG emissions and sequestration by issuing exchangeable carbon credits. Moreover, carbon markets use common market rules of supply and demand to control the price of carbon credits. There are two types of market: voluntary and compliance. In both types, polluters have to reduce their GHG emissions to a certain number of CO2 tons/year. If polluters cannot accomplish the target reduction, they can buy carbon credits from offset projects, or from other polluters who reduced their emission below what was set. The difference is that with compliance markets GHG emitters are forced to reduce their emissions by law or an agreement, while in voluntary systems polluters choose to participate. The most common design of a compliance market is a cap-and-trade system, while voluntary markets vary between what was described above and over the counter transactions (OTC), which are side transactions between a buyer and a seller. Currently the Kyoto Protocol is the major worldwide compliance market, which has set rules and reduction targets for all the participating countries. US has not signed the Kyoto Protocol, and currently does not have a national cap-and-trade system. Instead, it mostly relies on voluntary markets.

2.4.1 Emerging markets

Currently, however, in the US there is only one mandatory cap-and-trade system. Two others will start in 2012, but only California will have a cap. The compliance market Regional Greenhouse Gas Initiative was launched in 2009 and signed by ten northeastern states to offset and reduce emissions related to the use of coal to produce power. In 2008, California became the first state to pass legislation to cap GHG emissions statewide using a cap-and-trade system. Starting 2012, they plan to achieve the goal of reducing emissions in 2020 to the 1990 level. California is the pioneering state in this journey, and is certainly setting an example. Western Climate Initiative (WCI) will be another market-based system that should also start in 2012 (Western Climate Initiative, 2010). WCI is a regional agreement signed in 2007 by the governors of seven western states (Arizona, California, Montana, New Mexico, Oregon, Utah, and Washington) and the premiers of four Canadian provinces (British Columbia, Manitoba, Ontario, and Quebec). However, the cap-and-trade law did not pass when individually voted on by many states, limiting the participation to only California, British Columbia, Ontario, and Quebec (Western Climate Initiative, 2010) . Although only few governments will start in 2012, this cap-and-trade is still promising due to the economic importance those entities have in their countries. The rest of the states and provinces, which failed in participating, will join the extensive list of observers that include Mexican states, western American states, and other Canadian provinces. WCI and California Climate Action Registry (CCAR) will open for the participation of WA's forestland owners as offset suppliers.

Voluntary markets also allow WA's landowners to sell carbon credits generated in offset projects. Over the counter transactions are one kind of voluntary market where offsets are negotiated directly with a buyer, through an entity that has a protocol to guide how credits are generated. For example, NW Carbon Neutral® is a program developed by the Northwest Natural Resources Group (NNRG). This thesis will focus on CCAR because there is a published forestry offset protocol (Climate Action Reserve, 2010) (WCI does not have one), and on the NW Carbon Neutral® because it deals exclusively with western Washington forestry offsets.

NW Neutral ® intends to provide income for western Washington small landowners by rewarding their effort in maintaining their forests as carbon sinks and providers of environmental benefits to society. The program is directed at small landowners who are often prevented from participating in other markets due to transaction costs and their small capacity to offset GHG because of their small property size. NW Carbon Neutral ® was created by Northwest Natural Resources Group (NNRG) as an over the counter transaction (OTC) market to connect Western WA small forestland owners wishing to sell carbon offsets with preferably local buyers seeking to reduce their climate impacts. Thus, it should ease the participation of small landowners.

California Climate Action Registry (CCAR) was created in 2001 as a non-profit entity to manage and register GHG emissions from California by setting guidelines to the accounting of these gases (Pearson, 2008). As of March 2011, emitters voluntarily register their emissions, but this will change when the AB 32 full program gets implemented (set for 2012). CCAR has also created a comprehensive protocol for offset projects. It accepts offset credits from other states that are generated in compliance with the protocol rules. It does not have specific targeted landowners like NW Neutral ®, so small landowners should also be able to participate.

2.4.2 The role of offsets

Offsets play an important role in the market, and are the focus of this thesis. Offsets are carbon credits produced by entities, organizations, landowners, or people that are not forced to reduce their emissions. These projects must sequester, avoid, or reduce emissions of GHG beyond the business as usual practices. In other words, offset projects have to prove a net carbon reduction or sequestration, also called additionality. The extra carbon sequestered or not released generates environmental benefits paid by the carbon market. Offset projects meet additionality if they prove that net C gain would not happen without payment from the market. Moreover, offset projects need to discount a leakage rate because reducing GHG emissions or increasing sequestration often intensifies emissions in other regions. There is also a risk buffer zone that needs to be set aside for some types of projects such as forest offsets. This buffer zone works as insurance if loss of forest biomass occurs. Finally, offsets need to prove permanence, which means that the carbon stored will remain stored for a number of years. Forestry offset permanence is of 100 years. Forestry offset protocols are complex and have been constantly revised.

2.5 Land management for forest offset projects

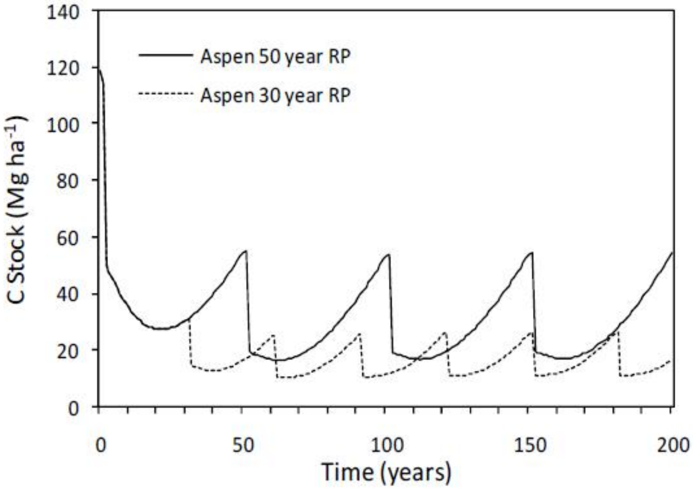
Forestry offset projects are relatively cheap and low maintenance (Diaz et al., 2009), especially for regions that already have monitoring programs in place and well developed forest sciences. Tree growth is one of the most assured ways of sequestering CO2, but forests commonly release great quantities of CO2 when natural disturbances or deforestation happens. There are also other issues associated with forest offsets or deforestation reduction such as the difficulty in finding accurate numbers for carbon stocks, lack of monitoring in tropical countries (Baker et al., 2010), proving additionality, and risk of offset reversal (unintentional release of carbon) (Galik & Jackson, 2009). Sequestering CO2 or reducing emissions through forest management can reduce climate change, but it is not the permanent solution (Harmon, 2009). Reducing the use of fossil fuel is the most powerful action to slow climate change to curb emissions.

Managing forests can maximize or reduce carbon stocks. Disturbances and harvest reduce carbon storage in forests, while fertilization, planting genetically appropriate seed sources for trees, and allowing the forest to grow without interference increases carbon sinking (Galik & Jackson, 2009; Lindauer-Thompson, 2008). There are three types of forestry offset projects that are acknowledged by its potential to increase C storage and are accepted in most carbon markets. They are afforestation/reforestation, extended rotation, and sustainable management.

Afforestation and reforestation clearly increase C storage on the landscape. Afforentation represents the planting of trees on lands that were forests more than 50 years ago, or on lands that have never held any forest (Pearson et al., 2008). On the other hand, reforestation reestablishes trees that had been logged or naturally displace not long ago. As trees grow, they store C in the ecosystem. It is also simpler to account for net increase of C in afforestation and reforestation projects and to prove additionality. Many restoration projects have relied on selling offset credits to cover the expenses (Ebeling et al., 2010).

Extended rotation is the delay of harvest for a number of years, which increases carbon storage on the landscape. Delaying clear-cut increases carbon stocks overall because it reduces disturbances and allows more carbon to accumulate in the soil, trees and wood products (Figure 4). The business as usual rotation in WA ranges from 35 to 45 years, so extending it to 60 or 80 years could increase C stocks.

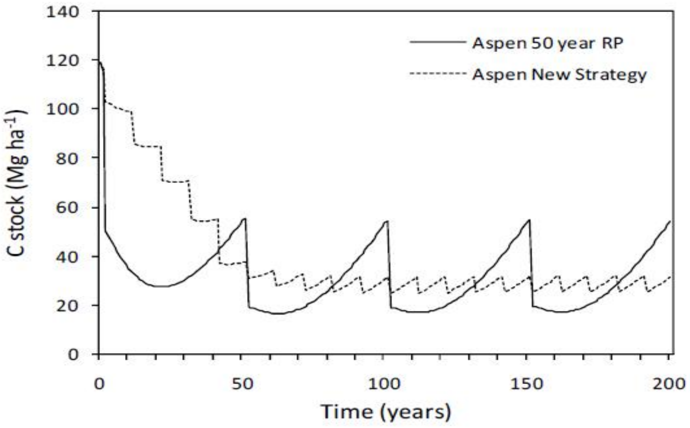
Figure 4*:* Comparison of C stocks in Aspen stands in Michigan under a 30 and 50 years rotation.



Note. This graph was adapted from Lindauer-Thompson, 2008.

Sustainable management maintains constant harvesting, but in small amounts throughout the years. This form of management stores more C than business as usual and extended rotations. For example, a landscape in Michigan that has 20% of its volume harvested every 10 years stored more carbon than clear-cutting in a 90 year rotation, and much more than the business as usual, which clear-cut every 50 years (Figure 5) (Lindauer-Thompson, 2008). This management strategy maintains habitat for certain species and a constant flow of timber and carbon credit income also reducing soil erosion and "boom and bust" economic effects.

Figure 5: Comparison of C stocks in an Aspen stand with different treatments: a 50 year clear-cut rotation and sustainable management harvesting 20% of volume every 10 years (called new strategy in the graph)



Note. This graph was adapted from Lindauer-Thompson, 2008.

This thesis focuses on the sustainable management as a strategy to participate in carbon markets because it suits the management implemented on this thesis' study site. Selling carbon credits not only requires a adequate management, but also a written management plan, a biomass inventory, project registration, and verification. The requirements have costs to the landowner and are referred to in the literature review as transaction costs. Transaction costs can be very high, possibly preventing small and medium landowners from making any profit with the sale of their offset credits (Galik et al., 2009).

2.6 Transaction costs

Transaction costs are the expenses of participating in carbon markets (Table 1). They are not related to the amount of carbon sequestered per hectare (Pfaff et al., 2007). Galik et al. (2009) compared transaction costs across markets and forest types and arrived to the conclusion that small and medium forestland owners cannot profit from participating in any of the most US popular carbon markets, including CCAR. Other authors also realize that land size can be a problem, but it may be possible that a significant income can be earned (Brooke, 2010; Diaz et al., 2009; Pfaff et al., 2007) Joining an aggregator should also increase profitability (Brooke, 2010; Diaz et al., 2009;

Pfaff et al., 2007) opposing Galik's et al. (2009) findings, which say that having an aggregator would increase a project's expenses which would ultimately reduce income.

Table 1: Costs related to generating forest offset credits.

Opportunity Costs	Foregone profits from harvests (through higher retention, longer rotations, etc.) or development.
Forest carbon inventory	Characterizes the pools of carbon in a forest, measures key carbon fluxes, and collects related data necessary to drive growth and yield models.
Forest Management Plan	Describes the objectives and prescribed management actions for the forest area, including a plan to measure and monitor carbon with quality.
Growth & Yield Modeling	Helps to value the carbon in the project through the manipulation of inventory data and the forest management plan.
Sustainable Forest Certification	A third-party certification that the forest is being sustainably managed. Most commonly obtained from the ATFS, FSC, or SFI.
Verification Fee	A third-party verification of information contained in the PDD is required.
Registration Fee	Most carbon offset standards have registries, which track the carbon pool through various transactions (re-sale of carbon offset projects is increasingly common) until it is retired, helping to prevent fraud.
Sales Fee	The CCX trading platform charges $0.20 cents per ton trading fee on all transactions. Carbon brokers also charge varying sales fees.
Sub-aggregator fee	The sub-aggregator fee covers expenses such as education & outreach, application review, data management in the aggregation process and general project oversight.
Aggregator Fee	The aggregator fee covers expenses associated with project development
Monitoring & Auditing	After the initial establishment of a carbon project, the landowner must keep their aggregator updated on changes in forest carbon stocks. Auditing is undertaken to ensure that the landowner is fulfilling their contract and that carbon is being sequestered at the estimated rate.

Note. This Table was adapted from Brooke (2010)

This thesis further investigates Galik's et al (2009) findings that transaction costs restrict income, and also the management strategy that optimizes revenue using a study site located in western Washington. Forest data was collected, and then entered into Forest Vegetation Simulator to forecast carbon stocks and timber harvest among different forest managements over the century. A cost-effectiveness analysis provided the results. This thesis reveals if transaction costs prevent small forest owners from profiting, and the best management option for the most revenue for a 60- year old Douglas-fir forest under various scenarios where carbon credit prices differ.

3. METHODS

3.1 Study site

The Heernett Foundation is a nonprofit environmental organization dedicated to restoring forest and wetland ecosystems existing on its 323 hectares property. The land is located in Tenino, Washington (Township 16 N and Range 1 W). The elevation in this area is about 5,000 feet above sea level and the climate is typical of the western Cascades, mild and wet year round with the exception of dry summers. This thesis is based on the characteristics of a 48 hectares stand (section 23, T16N, R1W) that has been managed in compliance with Forest Stewardship Council (FSC) standards in order to keep the certification. A certification such as FSC is required in order to participate in both CCAR and NW Neutral carbon credit programs further limiting my study site to this stand.

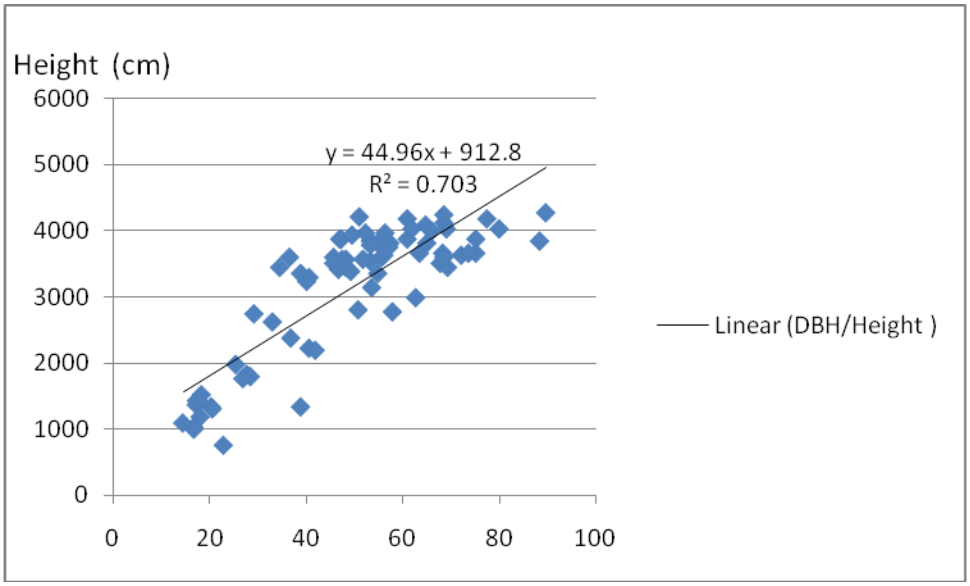
This FCS stand managed by Heernett Foundation has been thinned to an average spacing of 3 meters between trees, yet this is highly variable throughout the stand, which has an average of 340 trees per hectare. The forest is 60 years old composed Douglas-fir being the dominant, red-alder as co-dominant, followed by western cedar and big leaf maple. This composition is the result of a clear-cut that took place 60 years ago replanted with Douglas-fir. The understory is dominated by sword fern and Oregon grape indicating higher temperatures and slight to moderate dry soil (mesic towards xeric). The stand was divided by the foundation’s forester into 6 sub-stands of two kinds: one comprising a mix of red alder and Douglas-fir, and the other is exclusively Douglas-fir.

3.2 Biomass inventory

Inventorying forest C requires measuring carbon pools, rather than fluxes. Quantifying C fluxes is useful in understanding the processes of C storage and in comparing sites, yet fluxes are not stocks. C concentrates in 6 different pools: standing trees (living and dead), forest floor, belowground (roots and buried wood), soil, understory, and downed wood debris (logs and stumps). However, Market protocols dictate how pools are accounted for in offset projects. Some pools are not counted in particular projects while others include C stored in wood products. I estimated these pools by producing a biomass inventory using two different methodologies: (1) hand calculations using biomass equations and volume formulas and (2) data entry into Forest Vegetation Simulator (FVS). Both methodologies required field data collection such as tree measurements and observed site characteristics.

Field data collection for this project took place on eleven stratified timber plots, each measuring 25m in diameter. These individual study sites of 0.05 hectares represented 1.2% of the 48 hectare FSC-certified timber stand. Larger plot sizes of 0.05 hectare and over are recommended for old growth or thinned forests in order to encompass about 20 trees per plot (Willey & Chameides, 2007). For trees measuring over 5 inches in diameter at breast height (DBH),measurements we attained by using a diameter tape and height measurements were taken with laser points. Thirty meters diameter plots surrounding the original 25 meters plots were set in order to account for logs greater than 7.5 centimeters diameter. Transects were run within the larger plots in all cardinal directions. Only intercepted logs have their length and diameter at the intercept point taken, and decay class noted. Tree height for 3 plots was estimated using linear regression with data from the 8 previous plots. Figure 6 shows linear regression for Douglas-fir (*Pseudotsuga menziesii*), but linear regression was also used for other species. This was the data collected on the field used for the manual calculations and partially on Forest Vegetation simulator (FVS).

Figure 6: linear regression of Douglas-fir DBH and height.



Although two biomass inventories were produced, the thesis' results were based on the numbers generated by the FVS. The results of the manual calculated inventory were only used for comparison with the computer calculated FVS carbon estimates.

3.2.1 Manually Calculated biomass inventory

Estimates of total aboveground live tree mass was calculated using methods developed by Jenkins et al. (2003) and other authors listed in the BIOPAK (Means et al., 1994). The BIOPAK is a set of biomass equations developed by many authors that were gathered by Means et al. (1994), and compile in one document. Equations developed by Jekins et al. (2003) were used for red alder (*Alnus rubra*) and big leaf maple (*Acer macrophyllum*) because the BIOPAK (Means et al., 1994) provided limited choices that complied with my collected data. For example, some of the available equations for estimating total aboveground biomass required measurement different than DBH and height. Jekins et al. (2003) equations were developed to encompass large-scale properties and cross-regional trees. However, reliable regional equations are better when dealing with a small site such as the Heernett Foundation. Thus, I used regional equations from the BIOPAK (Means et al., 1994 *) that suited the collected measurements (Table 2).

Precise height measurements provides a bit more accurate results (Jekins et al., 2003), yet such precision is difficult to obtain and for this reason is not required for the allometries developed by Jekins et al. (2003).

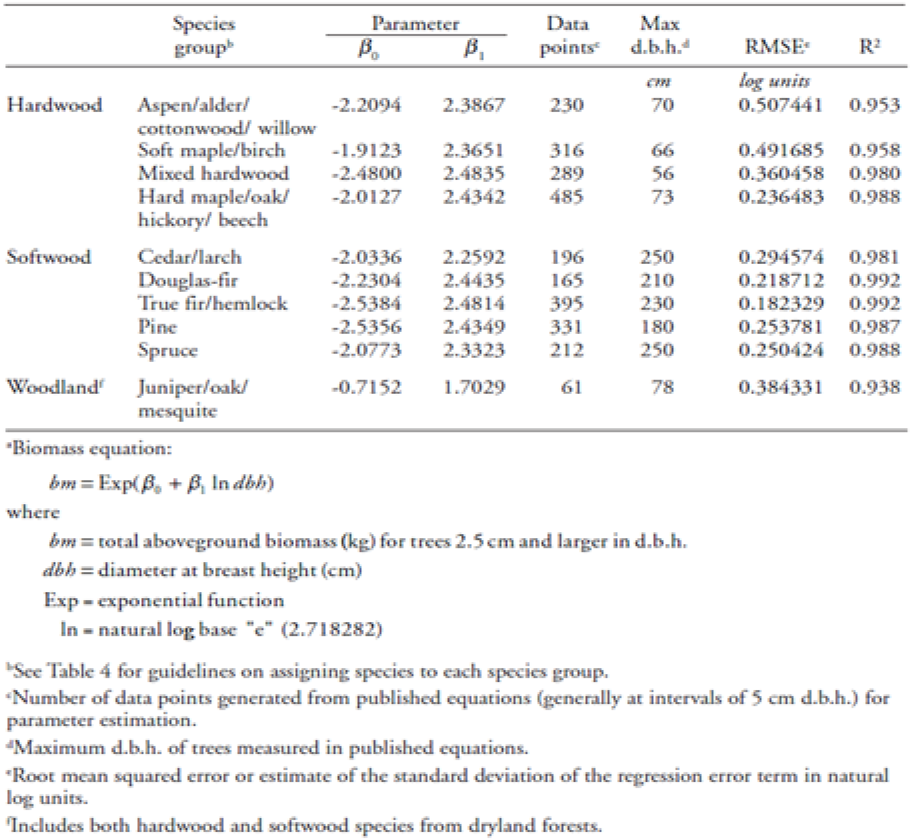
Biomass equations correlate DBH, height and other tree measurable characteristics with biomass. In addition, it is best to use equations that incorporate all the aboveground biomass such as branches and foliage. Allometries provide oven dry weight of a tree, of which 50% is C (Clark et al., 2001). Roots of the encountered tree species normally weight 20% of the total aboveground mass (Jekins et al., 2003). Errors potentially occur when using allometries (Jekins et al., 2003). Although they are society's best developed tool, they do not perfectly represent reality.

Table 2: Biomass equations from BIOPAK

Species	Equation	Unit	Reference
Pseudotsuga menziesii	BAT = 1054 + 0.2057 * (DBH^2*HT)	Centimeter, gram	Shaw, D.L, Jr. Biomass equations for... p.763-671. in W.E. Frayer, ed. Forest Resource Inventory - Vol.II. Proc. of workshop 1979 July 23-26 sponsored by SAF, IUFRO, Col. State Univ.
Thuja plicata	BAT = 1270 + 0.1501 * (DBH^2*HT)	Centimeter, gram	Shaw, D.L, Jr. Biomass equations for... p.763-671. in W.E. Frayer, ed. Forest Resource Inventory - Vol.II. Proc. of workshop 1979 July 23-26 sponsored by SAF, IUFRO, Col. State Univ.
Abies grandis	BAT = 30200 + 0.1469 * (DBH)2 * HT	Centimeter, gram	Standish, J.T. et al. 1985. Development of biomass equations for British Columbia tree species. Inf. rep. BC-X-264. Pacific Forest Research Center. Canadian FS

*BAT is the total aboveground biomass weighted in grams, DBH is diameter at breast height in centimeters, and HT is height in centimeters.

Table 3: biomass equations developed by Jekins et al (2003)



	Species group[b]	Parameter β_0	Parameter β_1	Data points[c]	Max d.b.h.[d]	RMSE[e]	R^2
					cm	*log units*	
Hardwood	Aspen/alder/ cottonwood/ willow	-2.2094	2.3867	230	70	0.507441	0.953
	Soft maple/birch	-1.9123	2.3651	316	66	0.491685	0.958
	Mixed hardwood	-2.4800	2.4835	289	56	0.360458	0.980
	Hard maple/oak/ hickory/ beech	-2.0127	2.4342	485	73	0.236483	0.988
Softwood	Cedar/larch	-2.0336	2.2592	196	250	0.294574	0.981
	Douglas-fir	-2.2304	2.4435	165	210	0.218712	0.992
	True fir/hemlock	-2.5384	2.4814	395	230	0.182329	0.992
	Pine	-2.5356	2.4349	331	180	0.253781	0.987
	Spruce	-2.0773	2.3323	212	250	0.250424	0.988
Woodland[f]	Juniper/oak/ mesquite	-0.7152	1.7029	61	78	0.384331	0.938

[a] Biomass equation:

$$bm = \mathrm{Exp}(\beta_0 + \beta_1 \ln dbh)$$

where

bm = total aboveground biomass (kg) for trees 2.5 cm and larger in d.b.h.

dbh = diameter at breast height (cm)

Exp = exponential function

ln = natural log base "e" (2.718282)

[b] See Table 4 for guidelines on assigning species to each species group.

[c] Number of data points generated from published equations (generally at intervals of 5 cm d.b.h.) for parameter estimation.

[d] Maximum d.b.h. of trees measured in published equations.

[e] Root mean squared error or estimate of the standard deviation of the regression error term in natural log units.

[f] Includes both hardwood and softwood species from dryland forests.

*Note: this Table was extracted from Jekins et al. (2003)

**The equations applied for red alder and big leaf maple were for the species group Aspen/alder/cottonwood/willow and Soft maple/birch

The biomass of stumps, logs and snags was calculated by determining the volume and decay class. The volume of snags was estimated by the formula V= L (Ab+At)/2, where V is volume, L is length and Ab and At is the area for the base, middle and top, assuming top diameter is half of DBH (Harmon & Sexton, 1996). While volume of stumps and logs was defined by the formula V= Am*L, where V is volume, Am is the area at the midpoint, or intercepted diameter, and L length or height. This formula assumes that the log is round, and it was used for all logs and stumps even though they often acquire elliptical or other forms. There are other equations to adapt the formula to other wood shapes, but due to their insignificant statistical difference, they were not used in this thesis.

Wood density varies according to species and decay class. Harmon & Sexton (1996) were able to define wood density for each decay class of the most common tree species in the Pacific Northwest and other regions (Table 4). Density is the ratio of volume per mass (D = V/M), so having the density and calculated the volume, the oven dry mass of logs, snags and stumps was revealed.

Table 4: wood density for each species decay class.

Tree Species	Decay Class	Density (g cm-3)
Psedotsuga menziesii	1	0.450
	2	0.342
	3	0.277
	4	0.137
	5	0.148
Thuja plicata	1	0.318
	2	0.259
	3	0.248
	4	0.154
	5	0.143

Note. This Table was adapted from Harmon & Sexton (1996).

Carbon amounts for forest floor (fine woody debris with DBH less than 7.5 centimeters, litter, fine roots above mineral soil), understory (boles, crowns and coarse roots of trees with DBH less than 2.5cm, shrubs and bushes) and organic soil (organic C, including fine roots up to 1 meter below surface) C pools were imported from estimates reported by the US Forest Service (USFS) online carbon estimator (COLE) in order to complete the hand calculated biomass inventory. COLE offers reports for selected areas with a minimum of 10 km radius. The reports are based on data published by the Forest Inventory and Analysis (FIA), and on biomass equations developed by Jekins et al (2003).

COLE's report for Douglas-fir and red alder stands in the study site defined the C pool for forest floor, understory and soil as containing 21.4 and 4.4, 6.3 and 3.3, 94.8 and 115.2, respectively. Thus, for plots that are Douglas-fir and red cedar dominant I used the estimates for Douglas-fir stands, while for those plots mostly containing red alder I used the estimates for red alder stands, and the median for mixed plots.

3.4 Forest modeling for 100 years

The permanence criteria of both carbon markets studied in this thesis, NW® Neutral and CCAR, require landowners to enroll their forested lands in 100 years contract. In this thesis C pools and harvested timber volume were predicted using FVS. This forest simulator uses ecological concepts of western Pacific Northwest forests and stand measures and characteristics to estimate C stored on the study site throughout one century. FVS allows its users to apply different managements also reporting volume of timber harvested. Reports from FVS are widely accepted as a forest modeler.

3.4 Determining Baseline

Baseline reflects the amount of C stored in forest surrounding the offset project, where common management practices are applied. NW Neutral® and CCAR's protocol consider baseline to be the median of C stored in live trees throughout one management cycle. For the study site located in Tenino, the baseline is the average C retained in live trees during 40 year rotation cycles on Douglas-fir plantations located on the western portion of Washington with a discount of regulated non harvesting buffers such as riparian (Hanson, 2011; CCAR, 2010). In this case, the baseline for both is the same, and it was estimated using FVS.

3.5 NW Neutral® & CCAR transaction costs

Participation in the NW Neutral ® and CCAR require paying transaction costs. Those costs were estimated from information presented on NNRG's website (http://nnrg.org/NW-Neutral/nw-neutral-faqs) and CCAR's webpage (http://www.climateactionreserve.org/how/protocols), and from an email interview on 18/01/2011 with Kirk Hanson, director of NNRG Washington.

3.6 Calculating carbon credits

Both protocols have different rules for accounting carbon credits. NW Neutral® compares the actual amount of C in standing trees in the project area to the average stored in standing tree over a 40 year clear-cut rotation (the baseline = 150 C t/ha). Landowners are awarded for the C they have stored over the baseline at the day the land is enrolled.

They receive one payment for the extra C stored committing to conserve the current stock. Carbon credits of CO2 equivalent were defined by multiplying tons of stored carbon by 3.7, then discounted for accounting uncertainties to achieve a 95% confidence level and discounted again for reversal risk (20%). Meanwhile CCAR protocol allows projects to account for all carbon pools, except for soil. Sellable carbon credits were calculated according to rules existing in the protocol, and landowners are paid for C increments over the years.

3.7 Timber and carbon price long-term forecast

Publications analyzing timber value over the years have concluded that log price has remained relatively stable when adjusted for inflation (Lutz, 2002; Lutz 2003). With the exception of strong market disturbances, Douglas-fir log price reports for the Puget Sound region show that over the years log prices per 2.35 cubic meter (or 1thousand board foot) have remained within a price range of $338 (Adjusted for inflation 2006) during economic depressive years such as Regan’s presidential years and the recent economic crisis (2008, 2009, and 2010) to $790 when house market and other market factors were favoring this commodity **(**Mason, 2011). The log price used in this thesis to determine future values is the average price from 1981 to 2009 reported in 2006 nominal dollar value and adjusted for inflation by Mason (2011). This average of $528 was used as the timber value over the next century.

On the other hand, carbon credits are fairly new and vary with different markets such as the EEU and voluntary ones in the US. The current prices for credits in the US fluctuate, but average approximately $5 (Hanson, 2011; Latta et al., 2011). Because forest offset contracts are of 100 years, this thesis had to forecast carbon credits prices in order to complete the cost-effectiveness analysis. NW Neutral® only allows one sale of carbon credits, which happens in the present having no need to forecast carbon prices. Thus, I used the current value of $5 and the desired value of $20 for the economic analysis. I adapted forecasts developed by the EPA, and also used a constant price of $15 as suggested by Latta et al (2011) for carbon credits generated through CCAR. EPA made its forecasts on spring of 2008 prior to a national cap-and-trade bill being declined by congress that was previously approved by the House. The fact of having a mandatory national market would heavily influence carbon prices, and EPA forecasted under this scenario. EPA (ADAGE) _ scenario 2 estimated allowances to cost $37 in 2020, $61in 2030 and $159 in 2050. For this scenario, the median between prices in 2030 and 2050 was taken to estimate price on year 2040. For the following decades, prices grew exponentially at a 30% rate until completing the century. Prices were $207 for 2060, followed by $269 in 2070, $269, $349, $454, $590, $767, respectively until 2110. This forecast is unrealistic, but provides an interesting comparison with timber income. The second EPA forecast used is the EPA (ADAGE) _ scenario 10, where prices start at $28 in 2020, $46 in 2030 and $121 in 2050. In this scenario the median was also taken to estimate price in 2040, and price remained constant at $121 for the following years until 2110. It is almost impossible to correctly forecast 100 years into the future because too much changes in one century. However, it is still useful to make the analysis. Therefore, there are three very different forecasts: one very optimistic, but unrealistic; the second still optimistic but more realistic; and the third was pessimistic and realistic if carbon markets do not become successful.

3.8 Cost-effectiveness analysis

Revenue from timber and carbon credits were calculated discounting transaction and logging costs for the different carbon price forecasts scenario. This calculation produced the nominal value in US dollars. This result was then compared with a 4% discounted value. The value in the future was equal to the nominal value divided by 1 plus the discount rate squared by the period such as 30 years into the future. The formula is nominal value/(1+.04)^year. The discount rate was extracted from Latta et al (2011), who did a similar analysis in the article “Simulated effects of mandatory versus voluntary participation in private forest carbon offset markets in the United States”. Discount rate is an important part of the analysis because predicting income into the future has high risks, which are tentatively mitigated with the discount rate.

4. RESULTS

4.1 Biomass inventory and carbon report

4.1.1 Hand calculated carbon inventory

Hand calculating the biomass inventory for the study site generated the total of 489 tons per hectare without including soil. Carbon content was estimated for the 11 plots, and then averaged. Table 5 displays tree species, median DHB and carbon stocks per plot.

Table 5: trees and carbon contents distributed per plot

	Plot #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
	ACMA					1	1	2				
Tree Species	ALRU	2	7	3		12	2	1			14	3
	ABGR								1			
	PSME		9		13	10	18	6	7	18	13	16
	THPL	1		1				8			3	
	median DBH	55.3	44.7	54.5	53.9	45.3	35.5	54.6	50.3	51.6	34.7	49.4
	Live tree	244	257	58.9	315	529	234	352.	305	359	249	404
C ton/ ha	live below ground	48.9	51.5	11.8	63.1	105.8	46.9	70.6	61.0	71.9	49.9	80.9
	Snags	0.0	9.3	0.0	9.6	10.4	5.3	0.0	2.5	37.5	1.8	86.0
	DWD	11.2	26.0	127	22.4	0.0	30.2	1.9	56.5	16.1	3.0	57.4
	Stumps	1.0	11.0	0.0	68.4	0.0	7.2	143	0.0	172	242	0.0
	understory	6.3	4.8	3.3	6.3	4.8	6.3	6.3	6.3	6.3	4.8	6.3
	forest floor	21	12.9	4.4	21.4	12.9	21.4	21.4	21.4	21.4	12.9	21.4
	soil	94	105	115	94.8	105	94.8	94.8	94.8	94.8	105	94.8
	total	427	477	321.0	601.7	768.1	446.7	690.9	547.5	779.3	669.1	751.5
	total non-soil	333.1	372.9	205.8	506.9	663.1	351.9	596.1	452.7	684.5	564.1	656.7
Stand total	non-soil	489										

4.1.2 FVS biomass inventory

FVS generated a carbon report according to the measurements and site characteristics ranging from 2011 to 2110. The report relies on ecological rules for forest ecosystems in the region, on biomass allometries developed by Jekins et al. (2003) equations and on forest fuel estimates methodology. The current stocks are presented in Table 6 below.

Table 6: FVS carbon report for the study site

	Aboveground	Belowground		Stand	Forest			Total Stand
YEAR	Live	Roots	Dead	Snags/Stumps	DWD	Floor	Understory	non-soil
2011	251.8	52.9	0.0	0.0	64.5	30.6	0.4	400.2
2021	285.3	59.9	5.0	19.5	50.5	30.9	0.4	451.5
2031	311.4	65.3	8.6	33.8	49.2	30.6	0.4	499.2
2041	330.2	69.2	11.2	45.2	50.1	30.3	0.4	536.7
2051	345.4	72.3	12.7	55.3	51.0	30.0	0.4	567.2
2061	359.1	75.2	13.7	62.0	53.8	29.7	0.4	593.9
2071	371.3	77.7	14.4	70.3	54.8	29.4	0.4	618.4
2081	382.7	80.1	14.8	77.2	57.3	29.0	0.4	641.6
2091	393.2	82.2	15.0	84.8	58.7	28.7	0.4	663.2
2101	402.8	84.2	15.2	91.3	60.6	28.4	0.4	682.9
2110	402.8	84.2	10.3	76.0	61.7	28.0	0.4	663.4

**Note: this table was adapted from FVS*

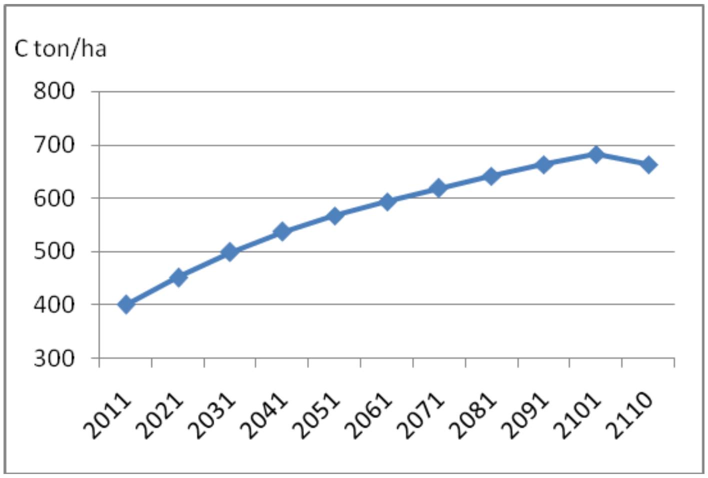
The result from the hand calculation method and FVS were different. The main reasons for such difference rely on the use of different biomass equations, diverse methodology to estimate down wood volume, and snag data was not input into FVS, which resulted in zero carbon content for this class. The difference is not significant due to the uncertainties that the science of measuring carbon faces.

4.2 Diverse management options of carbon storage and timber harvest

This thesis explored a diverse set of forest managements that include the sale of carbon credits and/or timber that could be applied to the Heernett foundation's stand. The different managements were modeled using FVS, and the goal was to compare revenue generated from both commodities under different strategies. Management options also varied if carbon credits were to be sold through CCAR and NW Neutral® because of different requirements and rules for carbon accounting.

The first management option is to leave the stand alone and let it grow naturally without harvesting. This option is accepted in both protocols, but the amount of carbon credits accepted for sale differs strongly. This no management strategy was modeled for one century complying with the permanence requirement. The forest will function as a C sinker (see Figure 7) proving additionality. A landowner who chooses this option will be relying on the sale of carbon credits as the main income, unless tax credits or other conservation income is received.

Figure 7: total non-soil carbon stocks over 100 years



A landowner call significantly different amounts of carbon credits when participating in NW Neutral® or CCAR. All carbon pools were included in CCAR calculations, which generated 1003 carbon credits per hectare over the following century. On the actual program, the credits would be given on a year basis, but to simplify the analysis over such long period the credits were reported every 10 years (see Table 7). On the other hand, if the FSC stand was enrolled with NW Neutral®, the Heernett Foundation would receive 86 ton/ha only in 2011 (Table 8). When payment for credits is received, the landowner has to maintain the current carbon stocks throughout the 100 year contract.

Table 7: Steps to determine the number of carbon credits issued by participating in the CCAR when no harvest occurs

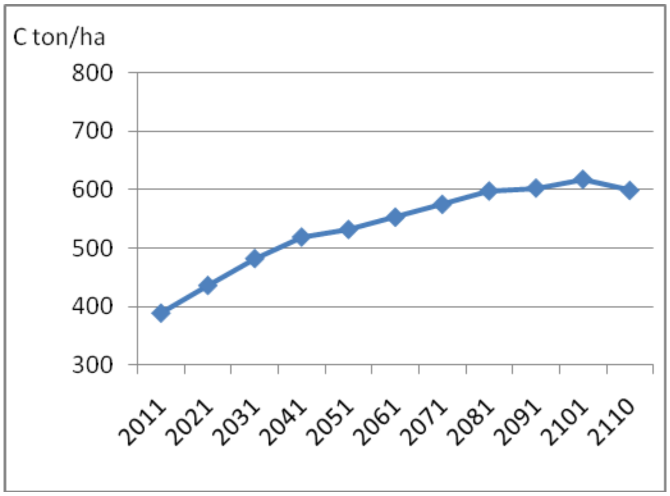
CCAR	2011	2021	2031	2041	2051	2061	2071	2081	2091	2101	2110
actual onsite C stock	400.2	451.5	499.2	536.7	567.2	593.9	618.4	641.6	663.2	682.9	663.4
confidence deduction	10%	10%	10%	10%	10%	5%	5%	5%	5%	0%	0%
adjusted stocks	360.2	406.4	449.3	483.0	510.5	564.2	587.5	609.5	630.0	682.9	663.4
10 year increment	360.2	46.2	42.9	33.8	27.5	53.7	23.3	22.0	20.5	52.9	-19.5
total net in co2	0	171	159	125	102	199	86	82	76	196	-72
risk	16%	16%	16%	16%	16%	16%	16%	16%	16%	16%	16%
Credits issued	0	143	133	105	85	167	72	69	64	164	0
total Ctrs/ha over 100 years	1003										

Table 8: NW Neutral credits accounting.

NW Neutral	2011
Live tree pool	304 ton/ha
uncertainty discount	3%
discounted C	296 ton/ha
risk buffer pool	20%
Total C	236 ton/ha
Credits equivalent (subtracted from baseline of 150 ton/ha)	86 ton/ha
CO2 equivalent	318/ha

The second forest management plan revolves around commercially thinning from below 10% of the basal area on 40 years cycle, and it is only compatible with CCAR's protocol. Harvesting would take place in 2011, 2051 and 2091. Only Douglas-fir trees larger than 10 inches DBH would be harvested. Then the site was be replanted with 98 trees per hectare without using fertilizer after every harvest. Biomass residue was left on the ground to naturally decompose. The fist replanting was done with western hemlock, the second with western cedar and the third with grand-fir, which helps the Heernett Foundation to achieve its biodiversity goals. Under this management, it was harvested 13.8, 21.9, 23.2 cubic meter (CB) of merchantable wood per hectare respectively in 2011, 2051 and 2091. The resulting total non-soil is shown on Figure 8.

Figure 8: total non-soil C stock over 100 years when 10% of the stand was thinned from below in 2011, 2051 and 2091



The management strategy 2 provides landowner with the option to harvest small amounts of timber and continue to generate carbon credits throughout the contract with CCAR. On this scenario the stand would generate 861 credits per hectare over the next century.

Table 9: steps for calculating C credits issued by CCAR for management option 2 (10% thinning)

CCAR	2011	2021	2031	2041	2051	2061	2071	2081	2091	2101	2110
actual onsite C stock	388.4	436	482	519	532	553	575	598	603	618	599
confidence deduction	10%	10%	10%	10%	10%	5%	5%	5%	5%	0%	0%
adjusted stocks	349.6	392.4	433.8	467.1	478.8	525.	546.2	568.1	572	618	599
10 year increment	0	42.8	41.4	33.3	11.7	46.5	20.9	21.85	4.7	45.1	-19
C removed	-11				-16				-15		
c stored in wood products	5.3	4	3.5	3.2	12	10	9.1	8.6	16.1	13.8	12.9
C increment in wood products	15.9	-1.3	-0.5	-0.3	8.8	-2	-0.9	-0.5	7.5	-2.3	-0.9
accountable C	0	41.5	40.9	33	20.5	44.5	20	21.3	12.2	42.8	-19.9
C credits in CO2 equivalent	0	154	151	122	76	165	74	79	45	159	-73.6
risk	16%	16%	16%	16%	16%	16%	16%	16%	16%	16%	16%
Credits issued	0	129	127	103	64	138	62	66	38	133	-62
Total over 100 years/ha	861										

The third management option thinned from below 20% of the basal area every 40 years. In this simulation only trees over 10 inches DBH were cut in the years of 2011, 2051 and 2091 followed by the replanting of 172 trees per hectare of western hemlock after the first harvest, Douglas-fir after the second, western cedar after the third. The trees were replanted without fertilizing and wood debris was left untreated. The 34.8, 48.9 , 64.4 CM of merchantable wood were harvested was per hectare, respectively in the harvesting years. C stocks continued to increase (Figure 9), and 575 carbon credits per hectare were sold through CCAR over the century (Table 10).

Figure 9: total non-soil carbon stock over 100 years under management option 3 (20% thinning)

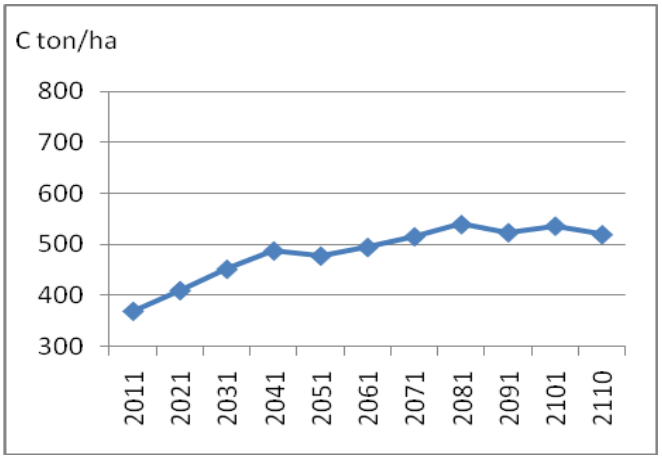


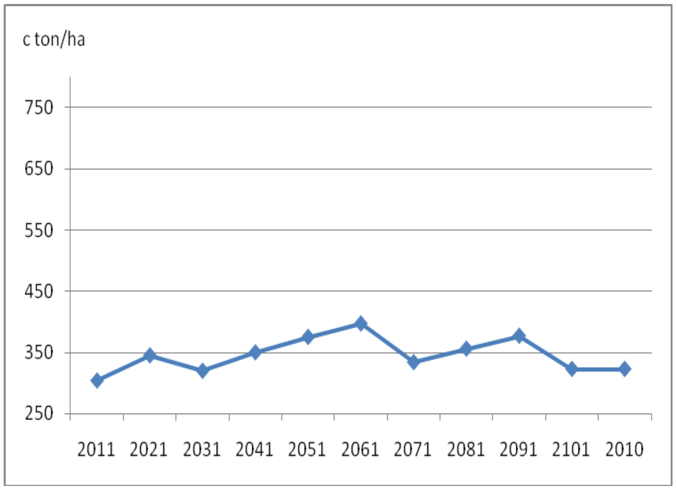
Table 10: steps for calculating C credits issued by CCAR for management option 3 (20% thinning)

CCAR	2011	2021	2031	2041	2051	2061	2071	2081	2091	2101	2110
actual onsite C stock	369.4	410	452	488	478	495	516	540	524	537	520
confidence deduction	10%	10%	10%	10%	10%	5%	5%	5%	5%	0%	0%
adjusted stocks	332.5	369	406.8	439.2	430.2	470.3	490.2	513	497.8	506.6	494.1
10 year increment	0	36.54	37.8	32.4	-9	40.05	19.95	22.8	-15.2	8.8	-12.5
C removed	-28.9				-38.3				-36.9		
c stored in wood products	14.9	11.5	10.2	9.4	30	25.4	23.3	22	41.6	37.3	35.3
C increment in wood products	6.3	-3.4	-1.3	-0.8	20.6	-4.6	-2.1	-1.3	19.6	-4.3	-2
accountable C	0	33.14	36.5	31.6	11.6	35.45	17.85	21.5	4.4	4.5	-14.5
risk	16%	16%	16%	16%	16%	16%	16%	16%	16%	16%	16%
Total accountable C	0	28	31	27	0	30	15	18	4	4	0
Accountable C in CO2 equivalent	0	103	113	98	0	110	55	67	14	14	0
Credits issued	0	103	113	98	0	110	55	67	14	14	0
Total credits issued over 100 years	575										

A forest owner could also sell carbon credits to NW Neutral® and continue to harvest for the following 100 years as long as the initial committed carbon stock is maintained. Because the carbon accumulated in the stand after the contract is signed cannot be sold in the future (unless a new contract is made), landowner might as well harvest the extra carbon. In this case the landowner will sell the amount of C inventoried in standing live tree pool in 2011 (304 ton/ha), and harvest the amount that exceeds the 2011 level. This way the landowner will receive income for carbon credits and timber.

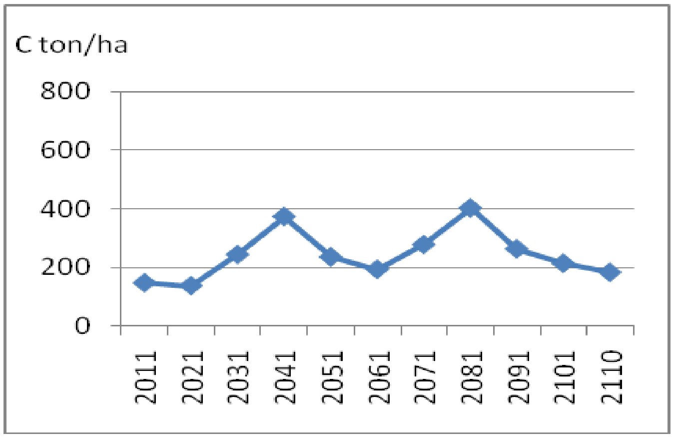
To accomplish this goal and to reduce costs and impacts of logging, the ideal management would be to harvest 20%, 25% and 25% of basal area of tress with DBH greater than 10 inches in 2031, 2071 and 2101. The harvest was followed by replanting of 123 western cedar, western hemlock and grand-fir trees per hectare, respectively. This management maintained C stocks above the minimum required (304 tons/ha) as shown in Figure 10. It was cut 76, 81.5, and 81.5 CM of merchantable wood per hectare, respectively in 2041, 2071 and 2101. There are other forms of logging this same amount of wood, which can vary with landowner's needs, timber prices and etc. However, this harvest percentage provides the maximum amount of wood, thus, ideally, the most income.

Figure 10: total non-soil c stocks when harvesting timber and joining NW Neutral®



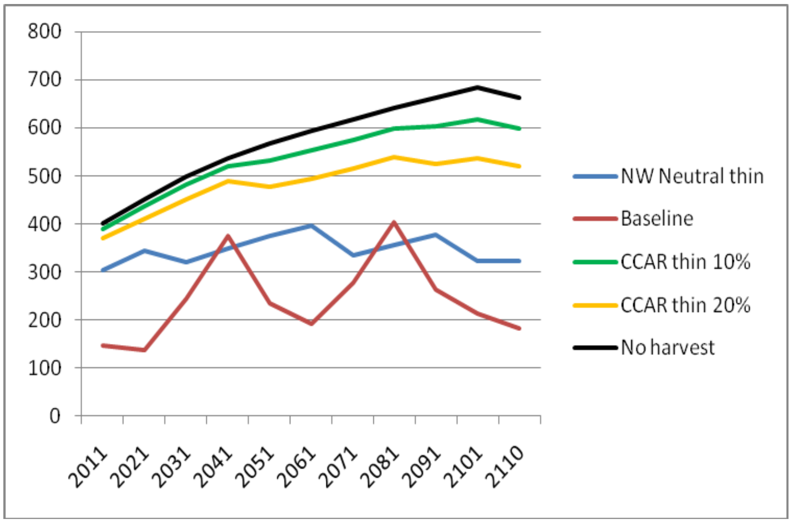
Finally the last management option, which is also the baseline, is clear-cut on 40 year rotation cycle. In the simulator, the stand was clear-cut in 2011, 2051 and 2091 leaving 12 30 inches or greater legacy trees per hectare followed by regular biomass treatment which makes it easier to replant. It was harvested 209.7, 215.6 and 227.2 CM per hectare. The site was replanted with 988 Douglas-fir trees per hectare using fertilizer (49 gallons per hectare). Figure 11 below illustrates the carbon pools for this management.

Figure 11: total non-soil carbon stock over 100 years under 40 years clear-cut rotation



The comparison of the carbon stored in the stand when different management options occur is clearly illustrated in the graph below.

Figure 12: comparison of total C non-soil across all the management options



4.3 Transaction costs

There is few transaction costs associated with selling credits in the NW Neutral market. Participation in this market is exclusive to western WA forestland owners that have NNRG's Northwest Certified Forestry (NCF) program membership. The membership costs $150 per year for organizations like Heernett Foundation (http://nnrg.org/nw-certified-forestry/Membership, 2011). In addition to being a member, landowners can only sell carbon offsets from FSC (Forest Stewardship Council) certified stands, which costs for my study site of 48 hectares (120 acres) $330 annually (see Table 8). A biomass inventory made by a professional forestry organization is also necessary, and costs vary from $49 to 123 per hectare depending on the property (Hanson, 2011). Third party verification and management costs are included in the FSC and NCF membership fees. FSC certified NNRG will negotiate the carbon credits and discount a 7% brokerage fee from the total amount paid to landowners. The total costs are then summarized in Table 11. Heernett's Foundation participation in this market would cost 8,000 every 10 years if no harvest occurs. In case there is harvest, another biomass inventory is required.

Table 11: Annual membership fees:

Associate	
Individual or Family	$50/year
Organization	$150/year
Certified	
Family (<100 acres)	$230/year
Small (101 - 200 acres)	$330 /year
Large (> 200 acres)	Negotiated

Table 12: expenditures required from forestland owners to sell carbon credits in the NW Neutral

Fees and costs	Dollar amount in 2011
NCF membership	**150/year**
FSC membership	**330/year**
Biomass inventory	**3,200-8,000/every timber harvest**
Monitoring	**Included in NCF membership**
Brokerage	**7% of sale**
Total up front	**3,700-8,500**

CCAR requires more expensive fees than NW Neutral. If Heernett Foundation enrolled its FSC stand with CCAR, the foundation would have to pay for all of the fees listed in table 13. The total amount using the lowest rates would be about $38,400 every 10 years. Monitoring and verification were estimated based on charges for biomass inventory. There was no organization or person available to extract the exact amount charged for monitoring and verification.

Table 13: CCAR transaction costs

Account Setup Fee	$500
Account Maintenance Fee (annual)	$500
Project Submittal Fee (per project)	$500
Variance Review Fee (per request)	$1,000
CRT Issuance Fee (per CRT issued)	$0.20
Account Transfer Fee (per CRT transferred, paid by seller)	$0.03
Account Holder Project Transfer Fee (per project transferred between account holders, paid by transferee)	$500
Retirement (per CRT retired)	no charge
Biomass inventory	$ 3,200-8,000
Monitoring	$ 500/ 2 years
Verification	$ 3,200-8,000/ 5 years

5. CONCLUSIONS

Transaction costs do not prevent landowners from making profit even when carbon credits cost as low as $5. However, it may not be worth going through the process of enrolling private small forests in carbon markets when prices are so low. NW Neutral® is more small landowner friendly than CCAR requiring less monitoring and other expenses, and providing more assistance. Transaction costs for CCAR are substantially higher than NW Neutral® resulting in a difference of approximately $3,000 per year.

A small landowner can only exclusively rely on carbon credit income if EPA's price forecasts are correct. However, when revenue is discounted with a risk rate of 4% none of the management strategies can substantially fulfill human needs of health care, food, education, transport and etc. The most a landowner can receive, when discounting the nominal value for a similar property to the study site is $20,000 per year under the traditional management of clear-cut.

When carbon prices are high and not discounted, it is better to manage Douglas-fir forests for carbon sequestration. However, when values are discounted, the best option for EPA's scenarios is thinning 10% of the basal area. Thinning 20% is only the best option for EPA's scenario 10 and only by $5 over. Estimates for carbon prices at constant $15 also change behavior when values are nominal or discounted. At the nominal value, timber oriented management increases revenue when carbon price is $15 and under. On the other hand, when low carbon prices are discounted, it is more profitable to manage for carbon sequestration. The discount rate significantly affects income because this analysis goes 100 years into the future, and too many uncertainties have to be accounted.

NW Neutral® had to be analyzed separately because carbon prices are not forecasted or discounted in the future. If a landowner enrolls his/her forest in NW Neutral®, it is best to harvest and replant throughout the contract maintaining carbon stocks at the initial level. Timber revenue substantially complement carbon credits income, but not as much when values are discounted.

There is a significant difference between timber and carbon revenue. Managing lands to store carbon was only more profitable under the most unrealistic scenario. In order to carbon sequestration management to be more profitable than the traditional clear-cut, carbon credits would have to cost at least $100. Even when timber is harvested to complement carbon credits income, it is still difficult for landowner to make a living exclusively from the forest. This situation varies with forest type and age, and property size. Bigger properties would have more costs, but also more income. It is not appropriate to generalize revenue estimates per hectare, neither across forest types. For example, income generated from carbon credits in Michigan Aspen forests overcomes timber revenue when carbon credits cost $26 (Lindauer-Thompson, 2008). The results of this thesis are clearly illustrated in Table 14.

Table 14: Revenue comparison in USD$ between carbon markets and management strategies.

No harvest (NW Neutral)	**Thin (NW Neutral)**	**Scenarios**	**No harvest (CCAR)**	**10% Thin (CCAR)**	**20% Thin (CCAR)**
when C=$5, $396/year	when C=$5, $17,179/year	EPA optimistic	$110,311/ year	$98,729/year	$55,879/year
when C=$20, $2,386/year	when C=$20, $19, 169/year	EPA constant	$42,642/ year	$40,126 /year	$31,749/year
		$15 constant	$ 3,916 /year	$18,403 /year	$12,562/year
Discounted 4%	when C=$5, $3,049/year	Discounted 4% EPA optimistic	$ 10,215/year	$ 12,072/year	$10,703/year
Discounted 4%	When c=$20 $5,039/year	Discounted 4% EPA constant	$ 6,814/year	$ 7,713/year	$ 7,718/year
		Discounted 4% $15 constant	$ 7,954/year	$ 5,457/year	$ 4,318/year
Baseline	Nominal=	$50,803/year	Discounted=	$ 20,592/year	

6. DISCUSSION

Carbon markets have the potential to be an effective tool to reduce GHG in the atmosphere. The financial incentive to landowners to change their management to sequester more CO2 can be a leverage point to change current levels of atmospheric CO2. However, carbon credits need to cost at least $15 to be used as a supplemental income. Relying on carbon credits like many landowners rely on timber as a major income will only be possible if credits cost approximately $80 and maintain this price throughout the 100 year contract. Thus, it is seems obvious that forest owners who enroll their land in offset project are inclined to conserve the land, which makes it more difficult to prove additionality. Some carbon markets such as CCAR accepts conservation easements as offset projects. When such projects are accepted, the validity of the project becomes questionable because if those are conservation lands anyway, how participating in the carbon market will affect global net C gain? In some cases the money earned in credits will help improve management to store more C, but in big picture little will change. Another issue of forestry offset projects is that forests slowly store carbon and eventually release it too, thus they are not capable of sinking all the CO2 emitted from the use of fossil fuels. Forestry projects have its limitations, but if protocols are well designed and carbon price high, it is possible to expect management changes in order to participate in carbon markets increasing overall carbon sequestration.

Permanence is a positive requirement of forestry protocols, but it possibly prevents forest owners from participating. 100 year contracts guarantee that the carbon stored today will remain in the ecosystem for one century. This is a gain for society, but a huge commitment to landowners. Their forests will be tied to a one century contract, and there will be penalties if contract is broken. Moreover, there may be many opportunities missed because of this contract. For this reason, carbon credits price must be attractive, or only conservation minded owner will turn their forests into carbon offset projects. Because of long contract and variable carbon price, it may be better for landowners, who are interested in being rewarded for the environmental and societal benefits their land provide, to enroll in other programs that provide tax abatement or payment that do not require the same things as a forest offset protocol. However, these rewarding programs are limited and become even scarcer when governmental agencies go through financial burden.

I would suggest to western Washington forest owners to wait a little longer before joining carbon markets. Emerging mandatory markets like CCAR and WCI may push credit prices up. In addition, businesses have developed environmentally friendly practices that include the purchasing of carbon credits, which may also contribute to raising prices. Kirk Hanson from NW Neutral® also tries to negotiate credits at a higher value, but it has not been possible at the moment. If carbon price rise, carbon markets will have an impact on how people, landowners and other entities will manage their business and make their choices.

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APPENDIX 1

Table 15: converting from metric to English units

1 hectare	2.47 acres
1 centimeter	.39 inches
1 meter	3.28 feet
1 cubic meter	35.5 cubic feet
1 cubic meter	.42 thousand board feet (MBF)