**DEPARTMENT OF
NATURAL RESOURCES**

**OFFICE OF THE
COMMISSIONER OF PUBLIC LANDS**
1111 WASHINGTON ST SE
MS 47001
OLYMPIA, WA 98504-7001

June 30, 2024

The Honorable Bernard Dean
Chief Clerk of the House
338B Legislative Building
Olympia, WA 98504

The Honorable Sarah Bannister
Secretary of the Senate
312 Legislative Building
Olympia, WA 98504

Dear Chief Clerk Dean and Secretary Bannister:

Please accept the enclosed legislative report regarding the Small Forest Landowner Carbon Work Group (CWG). The Department of Natural Resources (DNR) is submitting this report on behalf of the CWG as directed by Section 21 of the Climate Commitment Act (C 316, L 21). The bill directed DNR to contract with an eligible entity to establish and implement the goals of the CWG, which include identifying possible carbon market opportunities including the provision of offset credits and other incentive-based greenhouse gas reduction programs that Washington small forest landowners may be able to access. An interim report was submitted on December 29, 2022.

This report represents the culmination of work completed by Washington Farm Forestry Association (WFFA), along with several subcontractors, through a contract funded by the legislature. This final report includes a number of recommendations for future work and funding that may support the development of accessible carbon markets and incentive programs for small forest landowners in our state.

Should you have any questions, please contact me at 360-764-0013 or Brian.Considine@dnr.wa.gov.

Sincerely,

Brian Considine
Legislative Director
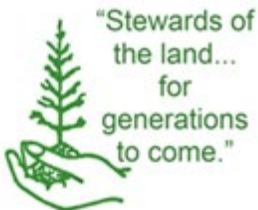Office of the Commissioner of Public Lands

Enclosure: Small Forest Landowner Carbon Work Group - Climate Commitment Act Legislative Report

cc: Members of the Senate Agriculture, Water, Natural Resources, and Parks Committee
         Members of the House Agriculture & Natural Resources Committee

Members of the Senate Environment, Energy, & Technology Committee
Members of the House Environment & Energy Committee
Members of the Senate Ways and Means Committee
Members of the House Appropriations Committee
Office of Financial Management

Small Forest Landowner Carbon Workgroup Established Under Section 21 of SB 5126 (2021) Climate Commitment Act
Legislative Report

Submitted By: Washington Farm Forestry Association
Dated: June 30, 2024

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Key Issues

Climate Change impacts and Forests as Solutions

Our climate is changing, and so are our forests and those who steward them. The Climate Commitment Act (CCA) of 2021 found that “Washington is experiencing environmental and community impacts due to climate change through increasingly devastating wildfires, flooding, droughts, rising temperatures and sea levels, and ocean acidification.” The CCA authors found that to address these impacts will “require coordinated, comprehensive, and multisectoral implementation of policies, programs, and laws” including those that recognize that forests and the forest sector play a unique and important role in Washington’s Natural Climate Solutions (NCS) toolbox. In essence, our forests are remarkably good at removing carbon from the atmosphere through photosynthesis, and our economic system is remarkably good at keeping it out of the atmosphere through turning that carbon into long-lived wood products.

But not all players in the system are equally equipped to take advantage of, or participate in, the policies, programs, and laws envisioned under the Climate Commitment Act. That too was recognized, resulting in a section especially to help identify and recommend policies that would support small forest landowners’ (SFLO) participation in the crucial work of providing natural climate solutions. The small forest landowner carbon workgroup (hereafter CWG) was authorized in Section 21 of the Climate Commitment Act to provide recommendations on programs and priorities that meet the needs of SFLO in the climate mitigation space.

Opportunities for much more investment in this critical infrastructure for climate change

Washington's 218,000 SFLO own nearly 2.9 million acres of forest, which annually sequester the CO_2 output of 875 thousand automobiles. This acreage corresponds to 15% of Washington’s forests and is typically located low in the watersheds near towns and cities, with ample opportunity for higher and better use (HBU) as development (Figure 1).

Whatcom
San Juan
Skagit
Okanogan
Ferry
Stevens
Pend Oreille
Island
Clallam
Snohomish
Jefferson
Chelan
Douglas
Kitsap
Lincoln
Spokane
King
Mason
Grays Harbor
Grant
Kittitas
Pierce
Adams
Whitman
Thurston
Lewis
Pacific
Franklin
Garfield
Yakima
Wahkiakum
Columbia
Benton
Walla Walla
Asotin
Cowlitz
Skamania
Klickitat
Clark
Washington Small Forest Landowner
Private / Tribal Industrial Forestland
WA Dept of Natural Resources
Other State
US Forest Service
Other Federal
County, Local
Conservation
Circa 2019 Washington State Forestland Ownership
Version 1.0 | Dec. 2020
Natural Resource Spatial Informatics Group
University of Washington | School of Environmental and Forest Sciences
Box 352100 | Seattle, WA 98195-2100 | https://nrsig.org
Citation: Cooke, Andrew G., J. M. Comnick, L. W. Rogers. 2020. Circa 2019 Washington State Forestland Ownership. Version 1.0. 2019 Washington State Forestland Database Series. Scale 1:2,240,000. Seattle, Washington, University of Washington.

Figure 1: Distribution of forest land and timberland in Washington State by Owner Type

The typical SFLO is aging out of active forest ownership and has inadequate succession plans, which often leads to the sale and conversion of forest properties to non-forest uses. Without effective SFLO support, including adequate technical and labor resources, the capacity of Washington’s small forests to mitigate climate change will be increasingly compromised, precisely when rapid expansion of these efforts is critically needed.

Emergent markets/mechanisms to connect small landowners to large opportunities

Within the realm of natural climate solutions, forests offer the most practical and cost-effective pathway to remove and store large amounts of carbon, both on the landbase and in long lived wood-based products. There are three pathways small family forest landowners can navigate to manage their forests in ways which will contribute to climate mitigation.

The three pathways are participation in: 1) a regulated forest carbon offset program, such as the Washington Cap and Invest program; 2) the voluntary forest carbon offset market, such as programs offered by ACR (rebranded name for American Carbon Registry), VERRA, and the Climate Action Registry (CAR); 3) incentive-based programs offered through federal and state agencies, such as Natural Resources Conservation Service (NRCS), state natural resource agencies, and non-profits such as the Family Forest Carbon Program – a joint program of American Forest Foundation and The Nature Conservancy.

Each of these pathways has benefits and risks to small forest landowners, as well as barriers to entry and impediments to participation due to programmatic requirements and time commitments. Due to these challenges, Washington small forest landowners have not been actively involved in either regulated or voluntary forest carbon offset programs, and only a small percentage have taken advantage of available incentive-based programs.

There are many good reasons for this lack of involvement, chief among them the cost and complexity of the process. The roadmap developed for this project (Figure 2) organizes this complexity into its key components. These components were tackled individually, with findings integrated to derive policy and funding recommendations that are most likely to overcome barriers and support SFLO participation in emerging markets for natural climate solutions.
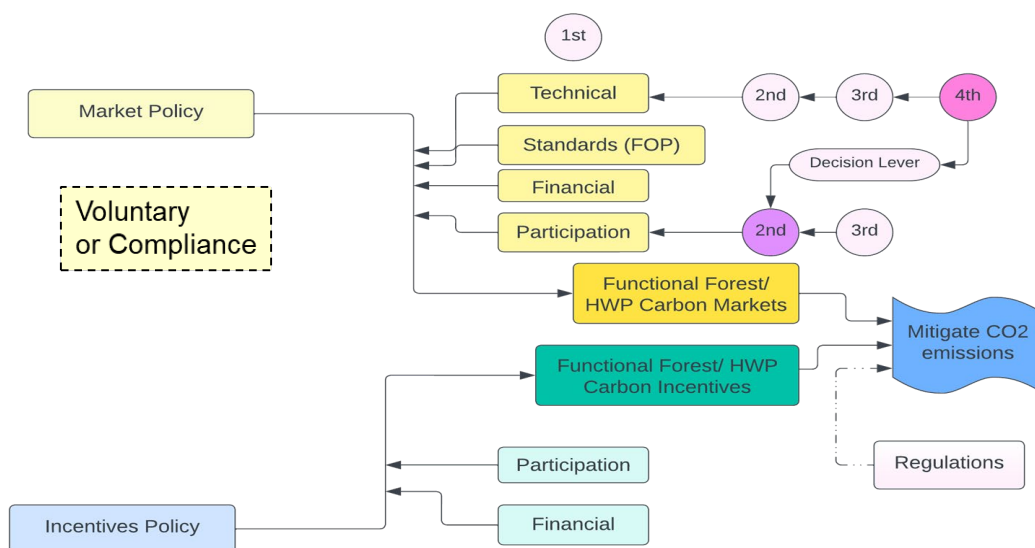
Figure 2: Small Forest Landowner Carbon Workgroup Road Map

Potential Scale of Impact

The scale of potential impact is enormous. Forestland owned by Washington's SFLO are low hanging fruit in our efforts to implement natural climate solutions as part of Washington's climate mitigation strategies. The scale of impact is driven by these elements: aggregate forest land area owned by SFLO, current forest condition, conversion risk, fire risk, and management intensity.

Potential improvements in SFLO carbon storage and sequestration are substantial

Data on Washington's forests from the USFS Forest Inventory and Analysis Program[1] were used in two different studies that examine carbon by ownership across Washington's forests. Through a contract partially funded by the SFLO CWG, the University of Washington Natural Resource Spatial Infomatics Group (NRSIG) generated the estimates of carbon stocks per acre for SFLO as compared to all forests as shown in Table 1. SFLO forests store approximately 17% less carbon per acre than the average of all of Washington's forests. Increasing carbon storage per acre represents a substantial opportunity.

Table 1.Total and average per acre forest carbon for SFLO and all forest in Washington state by pool (95% confidence intervals are listed in parentheses).

	Total Forest Carbon (MMT)		Forest Carbon Per Acre (Metric Tons)	
Pool	SFLO	All Forests	SFLO	All Forests
Aboveground live	71.2 (± 6.92)	841.4 (± 16.5)	28.0 (± 2.12)	38.1 (± 0.73)
Belowground live	15.3 (± 1.51)	185.7 (± 3.7)	6.0 (± 0.47)	8.4 (± 0.16)
Dead wood	22.4 (± 1.89)	261.7 (± 4.0)	8.8 (± 0.48)	11.9 (± 0.16)
Litter	24.9 (± 2.07)	273.7 (± 3.6)	9.8 (± 0.40)	12.4 (± 0.12)
Soil organic	88.8 (± 6.54)	762.4 (± 8.9)	34.9 (± 0.87)	34.6 (± 0.25)
Total	222.6 (± 17.1)	2324.8 (± 30.4)	87.5 (± 3.46)	105.4 (± 1.15)

A second study conducted in 2023[2] that used the same FIA data to conduct a trend or change analysis to estimate carbon flux from Washington's forests by landowner group (Table 2) found that SFLO forests also sequester (remove from the atmosphere) less heat trapping gases than other forests. In fact, on average they sequester about 44% less than the highest performing forests in the state. On a more positive note, SFLO forests hold on to more of the carbon they remove from the atmosphere as compared to forests owned by others.

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[1] USFS Forest Inventory and Analysis Program,

[2] Ganguly et al, 2023, in Washington Agribusiness Status and Outlook, WSU Impact Center.

Table 2. Forest and wood product carbon flux by owner type for Washington State.

WA Owner Group	Forest Account					Wood Product Account			Additions to Capital Accounts	Retained Carbon Ratio
	Current account (sequestration/acre)	Mortality/Decay (includes landfill)	Sequestration less decay	Net sequestration: sequestration	Forest Storage	Wood Products	Emitted (burned or otherwise depleted in mill) (by subtraction)	products less C used	Forest + product storage	Stock to Flux Ratio
Industry	4.93	1.65	3.28	67%	0.34	2.44	0.50	1.94	2.27	46%
DNR	4.09	1.79	2.30	56%	0.24	1.59	0.47	1.12	1.36	33%
USFS	2.88	2.05	0.83	29%	0.72	0.09	0.02	0.08	0.80	28%
SFLO/ Tribal	2.79	1.16	1.63	58%	0.93	0.58	0.11	0.47	1.40	50%

These two studies show that SFLO lands have significant opportunities for incremental improvement that will contribute to state climate goals without compromising other environmental benefits. However, more granularity is needed so that programs to support and encourage SFLO towards improved stewardship can be deployed effectively. Our recommendations speak directly to this need.

Conversion Risk

Because SFLO own land low in the watersheds and near towns and cities, their forests are under significant development pressure: it is much higher than the development pressure on other forests. Development usually removes the potential for ongoing carbon storage and sequestration as developed land uses are not compatible with maintaining and enhancing fully stocked forest stands. The 2021 study on Washington's SFLO found that their forests are converted at twice the rate of other forest lands. We can expect another 6% of SFLO lands (approximately 178,000 acres) to convert to non-forest uses by 2030 (Figure 3). Policy recommendations to stem the tide of conversion are critical as permanent forest cover loss affects natural climate solutions and may impact the potential for wood product storage solutions as well.
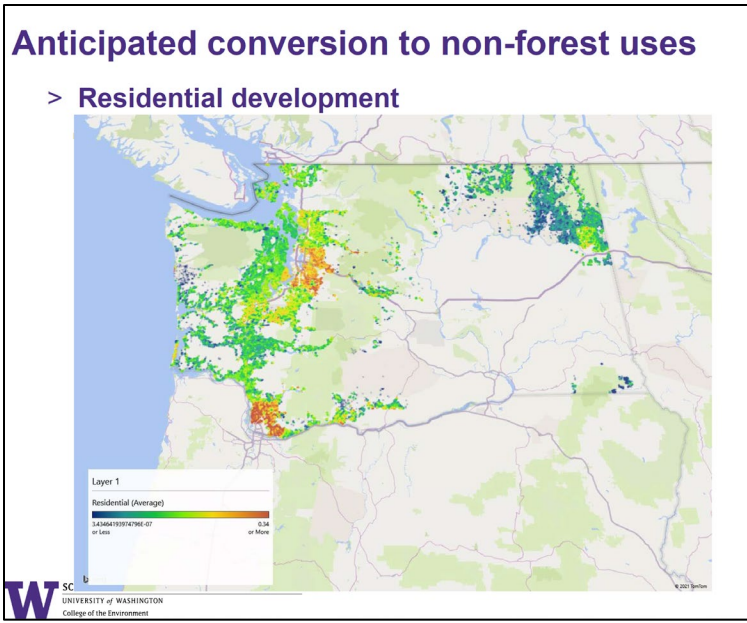
Figure 3: Expected conversion risk of forest land to non-forest land (2020-2030)

Source: Rabotyagov, et al, 2021, Washington's Small Forest Landowners in 2021

Fire Risk and Impacts

The Department of Natural Resources (DNR) 20 year forest health strategic plan identifies a significant portion of eastern Washington's forests at elevated risk for wildfire. SFLO own approximately 18% of forestland in eastern Washington. DNR fire risk assessments indicate that about 17% of the acres needing treatment to reduce fire risk are on SFLO lands. This nearly 1-to-1 ratio of fire risk to SFLO ownership provides a unique opportunity to link potential carbon market opportunities to fire risk reduction activities. It will require the state to establish incentives and policies that work in concert instead of against one another. Chief among them is reducing the significant regulatory barriers preventing the implementation of biochar-based technologies and infrastructure and building out coordinated approaches for its utilization.

Figure 4: Areas of high risk for wildfire in eastern WA (a) and eastern Washington Forest Land Ownership Patterns (b). Source: DNR 20-year forest health plan
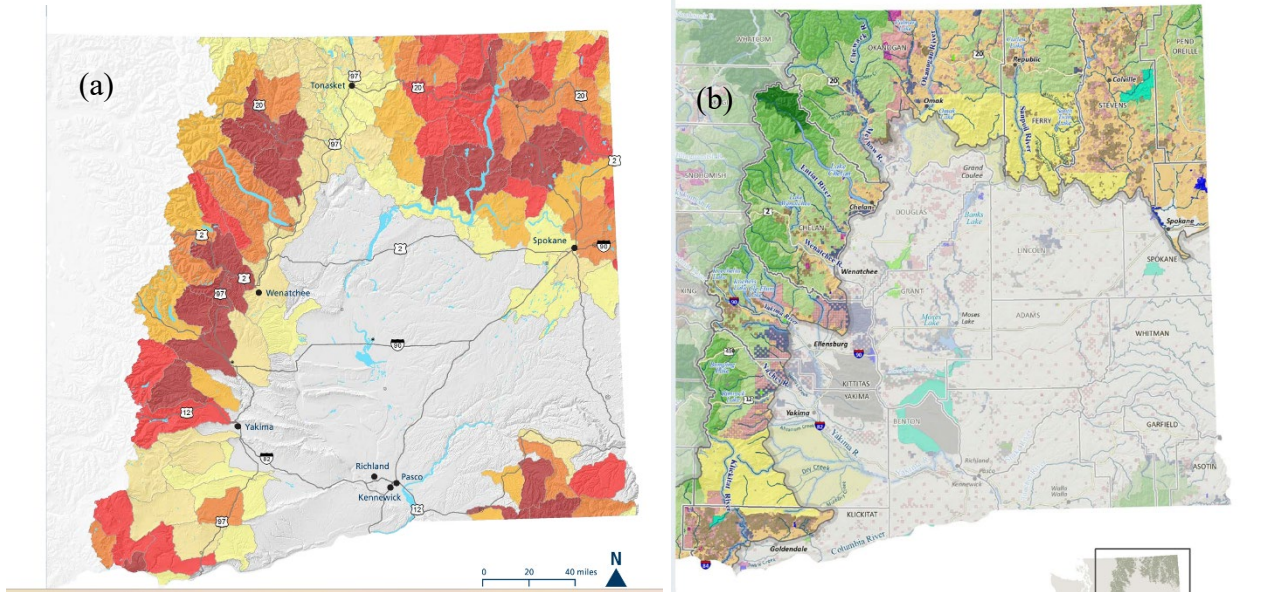
Contributions to Harvested Wood Products Carbon Storage

Washington's SFLO play a critical role in the forest sector, including providing about 12%[3] of the harvested biomass for Washington's wood manufacturing facilities. Most of the harvested biomass (about 75%) is directed to sawmills for conversion to long lived wood products[4]. Analysis conducted for the CWG found that for every cubic meter (m3) of sawn wood produced in Washington's sawmills, from 790 to 842 kg of CO2e is stored in the product itself after accounting for the emissions it took to grow, harvest, haul and manufacture it. Example substitution assessments were developed to compare the use of SFLO wood products versus functional equivalents which show an additional 35 kg CO2e of emissions are avoided by using wood in construction applications per square meter of wall area, or 1,666 kg CO2e per m3 of sawn wood for a total carbon mitigation benefit of about 2500 kg CO2e per m3 of sawn timber. Case study results translate to offsetting emissions from 65-98 car-years for every acre of well managed forest that is harvested. Harvest of lower quality sites or poorly stocked stands reduces the benefit proportionately. These estimates do not include the additional carbon stored in engineered wood products that are a co-product of producing sawn timber.

Combined Opportunity

Providing tools to small forest landowners to help them address fire risk, improve forest stand condition and sequestration potential, stem the tide of conversion, and make positive contributions to wood products storage are all part of a large matrix of opportunities that will

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[3] Palmer, Marin; Kuegler, Olaf; Christensen, Glenn, tech. eds. 2018. Washington's forest resources, 2007–2016: Ten Year Forest Inventory and Analysis report. Gen. Tech. Rep. PNW-GTR-976. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 75 p.

[4] TPO 2018

produce substantial contributions towards meeting Washington's climate goals. For example, if policies supporting keeping forests as forests were successful at reducing conversion, for every 1% reduction in forest land conversion the carbon benefit would equal - at a minimum - 3.8+% or nearly a 4:1 return on investment. This value assumes that the converted acres represent the average values in Table 1 and 2, and accounts for carbon stored in harvested wood products with average substitution benefit. If those same acres were managed to capture excess mortality from insects and disease, and improved forest management activities were implemented, then the carbon benefit would increase by another 2.6+% for a total gain of 6.5%. These cumulative benefits arise when we create policies that support keeping forest land as forest land, by supporting landowner efforts at maintaining forest health, capturing mortality when it occurs, and ensuring the infrastructure to process periodic harvests remains intact.

Barriers to SFLO Participation

Crafting policy that adequately captures this wide range of opportunities and challenges for participating in natural climate solutions is made more difficult by the size, diversity of goals, and skill level of the 218,000 small forest landowners across the state. Our work captured the following technical, economic and social barriers to participation in carbon programs:

Technical and economic barriers to entry

Small forest landowners wanting to engage in the carbon market, whether compliance or voluntary are faced with a laundry list of seemingly insurmountable challenges. These include:

1. **High Initial Costs**: The upfront costs associated with developing and verifying a forest offset project can be prohibitive for small forest landowners. These costs include the expenses of measuring and monitoring carbon stocks, preparing project documentation, and undergoing third-party verification.
2. **Complexity of Protocol**: The protocol for forest carbon offset projects is complex and technical. Understanding and navigating these requirements can be challenging for small forest landowners who may not have the resources or expertise to manage the rigorous demands of project development, verification, and ongoing compliance.
3. **Economies of Scale**: Carbon offset projects typically achieve greater financial viability with scale due to lower per-unit costs. Small forest parcels may not independently meet the minimum acreage requirements to generate sufficient carbon credits to attract buyers, making it less economically feasible for small forest landowners to participate without aggregating their lands with others, which is impractical for multigenerational commitments.
4. **Long-term Commitment**: Carbon offset projects require a long-term commitment to specific land management practices to ensure the permanence of carbon sequestration. In the case of the Washington Forest Offset Protocol, the initial crediting period is 25 years, with the requirement to maintain carbon stocks for 100 years after the end of the crediting period (minimum 125 years). This long duration is a significant deterrent for small forest landowners who need flexibility in their land management for economic or personal reasons.
5. **Restrictions of Forest Management Practices**: Restrictions on forest management practices contained in the Washington Forest Offset Protocol (FOP) are not practical for managing forest types found across Washington, such as Douglas-fir and hemlock

forests. In addition, prescriptive forest management requirements contained in the Washington FOP are not consistent with the Washington Forest Practices Act requirements. Examples include:
- even-aged harvest units may be no larger than 40 acres
- limits on the percentage of a single species of live trees within a project area based on a prescribed species diversity index by assessment area
- limits on age class distribution within watersheds
- prescriptive standing and dead wood requirements
- all forest parcels owned by a project participant must be third-party certified to the American Tree Farm program, Forest Stewardship Council, or the Sustainable Forestry Initiative

6. **Market Accessibility**: The market for carbon credits can be opaque and difficult to access for smaller producers. Without the knowledge or connections to find and negotiate with buyers, small forest landowners may find it challenging to sell their carbon credits at fair prices.

7. **Regulatory and Administrative Burdens**: The administrative burden of participating in carbon markets, including ongoing monitoring and reporting requirements, can be significant. For small forest landowners who typically do not have dedicated staff for such activities, these demands can be overwhelming.

8. **Lack of Tailored Support and Resources**: There is often a lack of targeted support, resources, and incentives for small forest landowners

Social barriers to entry

The technical and economic barriers must be interwoven with the social barriers to entry. As part of the CWG, a small-scale Ethnographic Futures Research study was conducted to identify key barriers to participation in a carbon market or carbon incentive program. Results were not what we expected. The report concludes with a nuanced understanding of the various factors influencing SFLOs' decisions regarding forest management and carbon sequestration. What we heard loud and clear is that the most important task we need to accomplish to overcome social barriers to entry in a carbon program is to 'grow community' so SFLOs are willing to engage, try new things, and feel like they have a safety net (financially, technically, socially) that will support them as (we all) advance into an uncertain future.

The Ethnographic Futures Report (Appendix 5) highlights a critical need for policy adjustments, educational support, and technical assistance to overcome the barriers to participation thereby decreasing the disincentives to engagement. The study's recommendations focus on creating an enabling environment for SFLOs, ensuring their practices are both sustainable and economically viable. By addressing these recommendations, there is a potential to significantly increase SFLOs' engagement in carbon sequestration efforts, contributing to Washington State's broader environmental and climate mitigation goals. In the end this study suggests a two-pronged approach. First, to develop policy, programmatic and practice-oriented recommendations that work to reducing the key barriers SLFO perceive as critical disincentives to participation. Second to develop targeted incentives that support engagement in carbon credit markets and climate smart forestry practices. Of major importance to developing such an important and large-scale program is to emphasize the shared common ground that is held in high values of the SFLOs who participated in this study and confirmed by other relatively recent research. The common

ground is for a future where the beauty, tranquility, privacy, wildlife and clean water of small forestlands are fundamental benefits that come from their stewardship.

In addition to the EFR work, a subcommittee gathered what data exists on environmental justice considerations for the CWG. There is nearly a complete lack of information on underserved communities as identified in the Climate Commitment Act. Based on 25 years of observation at WSU forestry field days, the majority of Washington's engaged SFLO are Caucasian and by virtue of their land ownership, wealthy (at least relative to their neighbors). In many cases, women and men share ownership and decision-making. Anecdotally there are some women-owned and managed forests as well, though no specific data are available on their numbers either.

Given there is so little data to make informed decisions with, we can only identify the obvious potential barriers for participation by SFLO from historically excluded and systemically oppressed communities. The primary barrier to participation in carbon markets by these communities is, first and foremost, a lack of access to forestland. Our focus must necessarily be on creating pathways to ownership. Barriers to ownership include, but are not limited to:

1) The high cost of forestland which, in areas with severe development pressure, is prohibitive;

2) Lack of awareness of resources and expertise, which are essential to support active management and stewardship of forestland. Applying climate smart forestry practices arguably necessitates an even greater level of forestry acumen. Research indicates that minority SFLO are less aware of existing networks of expertise than their Caucasian peers, and less trustful of these resources.

3) Lack of equity / representation in communities of support. SFLO typically have many communities of support available to them, ranging from local and regionally based Federal agencies like the Natural Resources Conservation Service and the Soil and Water Conservation Districts to state foresters and watershed councils, as well as nonprofit organizations like the Washington Farm Forestry Association. However, underserved populations may not see themselves represented in these communities—if they are even aware of them—and there may be few, if any, neighbors like themselves to call upon for advice and assistance.

4) Discriminatory practices, which have limited access to property, equity, and wealth generation. The well-documented history of redlining that has prevented people of color from accessing loans or purchasing properties in urban communities may be considered a proxy for challenges faced in rural communities.

Landowner Willingness to Engage
Additional surveys of SFLO willingness to engage in carbon programs were conducted during several educational events over the term of the project. By default, these surveys specifically target 'engaged' landowners that are ready to take the next steps in their land management journey because those are the kinds of landowners that show up to Forestry Extension Field days and WFFA events. The survey asked questions regarding willingness to implement and

minimum acceptable compensation for a range of potential carbon smart forestry practices as shown in Table 3 and Table 4 respectively. The practices included afforestation – i.e. planting trees on areas that are non-forest now – as distinct from reforestation which is required by law after harvest unless the landowner is converting to non-forest uses. They also include 'improved forest management', which is a catchall term that may include increasing stocking, decreasing stocking, addressing forest health concerns, mortality, or species issues depending on the condition of the forest relative to its capability. Extended rotation refers to increasing the age at which the land is harvested under the assumption that it is currently harvested before it reaches maximum carbon storage. Legacy forest management describes management action to put forests on a trajectory towards 'desired future condition' in areas that are currently off limits to harvest, usually due to regulation.

Table 3: Survey of Engaged Landowners – views on willingness to participate in various carbon strategies

Participation Willingness - Percentage of Respondents Answering "Yes"		
Intervention Type	Westside	Eastside
Afforestation	70%	67%
Improved Forest Management	88%	89%
Extended Rotations	71%	73%
Legacy Forest Management	84%	83%

Table 4: Survey of Engaged Landowners – Minimum acceptable compensation to participate in carbon incentive programs.

Participation Cost - Weighted Mean of Minimum Acceptable Compensation for Intervention			
Intervention Type	Westside	Eastside	
Afforestation	55	66	Percent of cost of implementation
Improved Forest Management	52	57	Percent of cost of implementation
Extended Rotations	6	5	Percent of timber value paid annually for deferred harvest
Legacy Forest Management	55	62	* Percent of total timber value for one-time compensation

Results show a preponderance of SFLO are willing to engage in climate smart forestry practices, even if they aren't entirely clear what they are. Consistent with other research and observations of SFLO behavior, they don't necessarily have to be fully compensated for all costs associated with these improvements, though there is significant variability in that finding.

A Tool Chest is needed

To enter the carbon market requires significant investment in inventory development, change detection, and verification. One of the technical tools needed to adequately address barriers and create opportunities for the adoption of natural climate solutions for SFLO is a method to reliably reduce forest sampling and inventory costs, identify locations that would benefit from intervention, and link the inventory to alternative management pathways and consequences for a

complete carbon assessment. The ideal tool would be able to aggregate multiple owners into a cohort of market participants and measure impact over time.

We have found some success in advancing on both tool and method development that is moving us rapidly towards being able to offer a proposed protocol built on remotely sensed estimates of forest inventory alone. Building on the data development and models funded by the legislature under SB 5330 (2019), the UW NRSIG was able to advance on sophisticated machine learning models combined with multiple remote sensing layers to develop high quality predictions of forest composition and structure. Their estimation procedures, with a few more refinements, could effectively serve as Washington's forest census (wall-to-wall inventory). Furthermore, it has a module in development that links the forest carbon estimates to harvested wood product and substitution carbon estimates for a more complete assessment of the carbon consequences of management alternatives. This tool development has outpaced that of all other data developers for forest carbon markets in the USA. This huge accomplishment is currently in review, with expectation for adjustments, refinements, and modifications to meet confidentiality requirements of the underlying data coming soon. To be truly effective, ongoing updates to underlying data will be needed. It will be suitable for assessing aggregate potential for compliance and voluntary carbon market transactions, as well as measuring benefits from carbon incentive programs.

A Synthesis of Recommendations

Figure 2 identifies the technical, protocol, financial, and participation levers that collectively are required to implement carbon market or carbon incentive policies in Washington state. Our analysis of the levers led to the following recommendations, that together will address the core requirements of the CCA legislative request.

Washington Forest Offset Protocols

To address the barriers and impediments for small forest landowner engagement in Washington's regulated market we recommend the Washington Department of Ecology revise Washington's Forest Offset Protocol (FOP) to simplify participation requirements, include less restrictive forest management practices, and shorten the required project period for small forest landowners. This recommendation will be carried forward to the current FOP revision working group that will convene starting July 2024 given that at least one member of the CWG has been chosen to participate in that group.

Programmatic Support for Ongoing Technical Tool Development

Dedicated programmatic funding for ongoing statewide assessment and monitoring of forest conditions and land use change is needed. For the past 20 years the NRSIG at UW has been 100% soft funded through a variety of short-term, product specific contracts. They have delivered literally millions of dollars of benefits to the state in the process of generating those deliverables. Currently funded efforts at the Washington State Department of Natural Resources are limited to state lands and statewide assessments are sporadically funded, inconsistent, and inadequate for cap-and-trade carbon markets. It makes no sense to continue this haphazard support of one of the best products in the country. There are a few different models for how this recommendation could be implemented:

1. Create legislation that enables the UW Precision Forestry Cooperative - which houses NRSIG - to be a UW Cost Center, much like CINTRAFOR (http://www.cintrafor.org/ - RCW 76.56). This would facilitate establishing a pathway for programmatic, legislatively dedicated funding for advancing these data products and tools.
2. Establish a new independent UW or collaborative higher-ed/agency organization to advance this work using a mechanism like the Advanced Technology Initiative that began the Precision Forestry Cooperative.
3. Establish a Public Benefit Corporation, starting with public support via a block grant to advance this work in a transparent and open way.

Of all these options, we believe the first one will deliver the most value to the state. It will also create the most respected and transparent data for carbon market transactions, and over the long term maintain Washington's lead in product development and artificial intelligence in using remote sensing to answer our most vital natural resource questions.

Programmatic Support for Landowner Engagement and Community Building

Despite the many resources available in the state to support SFLO, including help from Washington DNR, Conservation Districts, NRCS and WSU Forestry Extension, the message is not getting out there, or the one that is received is of total confusion. State and federal agencies are tasked with providing a broad spectrum of resources to SFLO that may include, but are not focused on, engaging landowners in climate smart practices or market programs.

Data from engaged landowners finds they are willing to engage in the carbon market and incentive space, but for the most part SFLO don't know what to do, where to start, who to trust, or if they can afford the time, energy, and effort it will take to implement the necessary changes on their forestland. They want to 'grow community' so they can feel supported as they embark on their journey of becoming part of a Community of Practice[5] centered on carbon smart forestry.

To address these barriers, impediments and gaps, we recommend that the Washington State Legislature provide funds, through a block grant from the Washington Department of Natural Resources or the Department of Commerce, to WFFA, a Washington non-profit operated under the direction of small forest landowners. This block grant would be used to create and operate a robust technical and market support program for small forest landowners where they can learn with their peers as they engage in providing critical climate mitigation services. The program would be tasked with:

- Building a Community of Practice centered on climate smart forestry.
- Building engagement with non-traditional and underserved communities.
- Educating and training small forest landowners on carbon mitigation and offset programs.
- Providing peer-to-peer mentorship through a navigator service to build landowner capacity in accessing financial, technical, and implementation support.

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[5] Thinking Together: What makes Communities of Practice Work

- Establishing a Washington partner to coordinate linkages needed to galvanize and support SFLO engagement in carbon markets and incentive programs.
- Serve as the vehicle for establishing a franchise of the American Forest Foundation's Family Forest Carbon Program (FFCP) in Washington.
  o Develop and Maintain MOU with FFCP
  o Develop proposed practices and standards that reflect the technologies and science NRSIG brings to the table and shepherd them through the standards development process.
  o Outreach/engagement to attract willing participants
  o Aggregation tracking and coordination
- Cooperate with forestry technical service providers, including agencies with well-established technical and financial offerings.

Financial Investment Tools for Climate Smart Forestry

We recommend that Washington state develop innovative pathways to finance investments in climate smart forestry practices targeted at small forest landowners. These include incentives directly to landowners, as well as the use of green bonds and the creation of a green bank.

Financial Incentives

- Offer loan or bond guarantees to reduce the cost of capital financing forest carbon projects that require patient capital recovery, including reforestation, fire risk reduction, and improved forest management carbon projects. Qualified forest carbon projects would be required to use a methodology approved by a credible, third-party entity, as determined by the Department of Ecology.
- Offer grants to small forest landowners that will assist in covering a portion of the upfront costs of developing a forest carbon project, such as the cost of a carbon inventory and third-party verification.
- Create a state insurance product or a state buffer pool for use by the private carbon marketplace as an alternative to depositing a portion of project carbon credits into a registry buffer pool account.

Green Bonds

Washington should adopt the use of green bonds to finance investments in climate smart forestry and to underwrite programs like the Family Forest Carbon Program expansion into Washington that will serve small forest landowners.

Green Bank

Washington should create a quasi-public green bank supported with $100 million in public capital to finance climate mitigation initiative, with a focus on small forest landowners.

- Green bank oversight from an appointed Board of Directors
- Capitalize with $100 million in public funds, which can leverage $500 million in private capital

- State should use several funding sources, including green bonds, the state climate investment fund, the state clean water revolving fund, and the state clean energy fund
- Legislation will be needed to create the entity, and possibly regulations to access certain forms of funding
- The Green Bank will need to hire dedicated staff, borrowing some administrative services from other agencies (Department of Ecology, Department of Commerce) at start-up
- Green Bank should offer a portfolio of financing and market development solutions, focused on initiatives that demonstrate a positive climate impact, a positive environmental justice impact, the ability to service low-interest repayments to the Bank, and direct positive impact for the state

Small Forest Landowner Carbon Workgroup Legislative Response

Legislative Authority

In 2021, the Washington State legislature passed the Climate Commitment Act (SB 5126), which established a cap and invest carbon emissions reductions program for the state. This program regulates the emissions of large entities in Washington by establishing an emission "cap" or limit, which will slowly decline, and creating an allowance system that enables these entities to purchase the right to emit over the cap if they are unable to reduce their emissions to comply with it. It also creates a carbon offset program, in which covered entities can invest in verified carbon projects (through the purchase of carbon credits) that prevent or reduce emissions, hereby balancing out the emissions from their operations. This offset mechanism is part of what is known as the "compliance market" for carbon credits.

Forests are recognized as a natural climate solution because of their vast ability to sequester and store carbon for decades and beyond. Washington State law also acknowledges the role that the forest sector plays in sequestering and storing carbon. While more evolutionary than revolutionary, the process of growing more trees and using more wood can lead to perpetual atmospheric CO_2 reduction, but the perpetual benefit requires a linked systems approach. This linked systems approach is reflected in SB 5126 Section 21 and its reference to Section 19 (offsets) which references RCW 70A.45.090 regarding the forest and forest products sector carbon sequestration potential of the state that codifies the findings of ESSHB 2528 (2020).

Prevention of forest loss, changes to forest management practices, reforesting or afforesting areas without forest cover, and wise use of harvested wood products (HWP) are all crucial ways to enable forests to continue to play—or to enhance—this essential role in mitigating climate change. A known challenge with advancing successful forest carbon projects, however, is that the expertise, data, and financial resources necessary for implementation are so significant that landowners with small forest land bases are typically precluded from participating.

Small Forest Landowner Carbon Workgroup Deliverables in SB 5126 Section 21(1)

The legislature acknowledged this challenge and sought to address it in the Climate Commitment Act by establishing a Small Forest Landowner (SFLO) Work Group.

"(1) The department of natural resources must contract with an eligible entity capable of providing public value to the state through the establishment and implementation of a small forestland owner work group. The purpose of the work group is to forward the goals and implementation of this chapter by identifying possible carbon market opportunities including, but not limited to, the provision of offset credits that qualify under section 19 of this act, and other incentive-based greenhouse gas reduction programs that Washington landowners may be able to access, including compliance markets operated by other jurisdictions, voluntary markets, and federal, state, and private programs for forestlands that can be leveraged to achieve carbon reductions." (SB 5126, Section 21, page 50)

....

"(3) The work group must transmit a final report to the department by December 1, 2022, that provides recommendations for incentives, the implementation of incentives, and payment structures necessary to support small forest landowners and any recommendations around extending the work group or making the work group permanent. The department must submit the final report to the legislature, in compliance with RCW 43.01.036, by December 31, 2022.

(4) For the purposes of this section, "eligible entity" means a nonprofit entity solely based in Washington that can demonstrate a membership of at least 1000 small forestland owners and that has, as part of its mission, the promotion of the sustainable stewardship of family forestlands." (SB 5126, Section 21, page 50-51)

Workflow organization in response to SB 5126

Response to SB 5126 Section 21(1), 21(3), 21(4)

The eligible entity was identified as the Washington Farm Forestry Association (WFFA), a 501 c (5) non-profit that has been continuously registered in the state of Washington since February 1953. The Washington Farm Forestry Association is a membership-based organization of, and for, small forest landowners in Washington State who embody a land ethic as '*Stewards of the Land ... For Generations to Come*'. WFFA is the longest continually operating *Community of Practice*[6] for small forest landowners in Washington state. Given the history and development of tree farming, which began in 1941 in Montesano, Washington and served as the organizing principle driving the establishment of WFFA, it may be the oldest Community of Practice for small forest landowners in the entire USA.

WFFA members own from a few acres to a few thousand acres and manage them for timber, other forest products, wildlife, fish, recreation, and aesthetics. WFFA represents over a thousand tree farming families from across Washington and has as its core objectives

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[6] Thinking Together: What makes Communities of Practice Work

educating small landowners about improved management of forestland, representing small forest landowners in legislative and regulatory processes, and educating the public on the contribution of small forest landowners to the environment and rural economies in Washington.

Due to funding and contracting delays, the contract between the Department of Natural Resources and the Washington Farm Forestry Association to complete the small forest landowner carbon workgroup tasks was finalized on November 1, 2022. An interim legislative report describing how the work would be organized, details on participation, and expected outcomes was delivered to the legislature on December 31, 2022 with the expectation that a final product that is responsive to objectives detailed in SB 5126 S.21would be delivered by June 30, 2024. The small forest landowner carbon workgroup met from November 2022, through January 2024. Subsequent contract work was completed between January 2024 and June 2024 to finalize core objectives of the project.

Small Forest Landowner Carbon Workgroup Deliverables in SB 5126 Section 21(2)

The small forest landowner carbon work group was tasked with completing several specific objectives consistent with the language in SB 5126 as follows:

"(2) The work group established by the eligible entity under this section must:
(a) Provide recommendations for the implementation and funding of a pilot program to develop an aggregator account that will pursue carbon offset projects for small forestland owners in Washington state, including recommendations based on programs established in other jurisdictions;
(b) Coordinate with the department on the development of offset protocols related to landowners under section 19(4)(d) of this act;
(c) Develop a framework and funding proposals for establishing a program to link interested small forestland owners with incentive-based carbon reducing programs that facilitate adoption of forest practices that increase carbon storage and sequestration in forests and wood products. The framework may include:
(i) Identifying areas of coordination and layering among state, federal, and private landowner incentive programs and identifying roadblocks to better scalability;
(ii) Assisting landowners with access to feasibility analyses, market applications, stand inventories, pilot project support, and other services to reduce the transaction costs and barriers to entry to carbon markets or carbon incentive programs; and
(iii) Sharing information with private and other landowners about best practices employed to increase carbon storage and access to incentive programs; and
(d) Recommend policies to support the implementation of incentives for participation in carbon markets.

Response to SB 5126 Section 21(2)

Data collection efforts required to meet the requirements of SB 5126 section 21(2) have been organized into three components. The components are: Task a) data collection on existing carbon policies, including information from existing programs proponents, and stakeholders; Task b) identifying the barriers Washington's small forest landowners face and quantifying what they need in order to meaningfully participate in compliance and voluntary markets; and Task c) understanding the science of carbon in the forest and wood products stream and characterizing how best to quantify its accurate and reliable prediction to inform policy recommendations and meet market protocol and verification requirements.

Task a) was conducted by WFFA and subcontractors with expertise in carbon accounting, carbon protocols, communications, and community connections. Task b) was conducted by WFFA and subcontractors with expertise in community outreach, ethnographic futures research, and environmental justice. Task c) was completed under subcontracts to the University of Washington School of Environmental and Forest Sciences Precision Forestry Cooperative research group called the Natural Resource Spatial Infomatics Group and to the Consortium for Research on Renewable Industrial Materials (CORRIM).

The UW element of task c) was a critical step in determining if an aggregator account could be established in Washington consistent with approaches for the American Forest Foundation's Family Forest Carbon Program (FFCP) protocol. The FFCP dynamic baseline protocol was recently accepted by Verra, a carbon registry that manages the Verified Carbon Standard (VCS) program. Verra is the most widely used carbon registry in the world. Recommendations on developing a pilot program for an aggregator account that can be mirrored in the Verra protocol depended in large part on the results from the University of Washington spatial analysis as there is a substantial technical hurdle to address to meet uncertainty requirements for the sale of carbon credits. The CORRIM piece of task c) links the UW generated inventory data to harvested wood product (HWP) outputs as required by RCW 70A.45.090 to fully quantify the carbon consequences of alternative carbon pathways.

A core requirement of the contract language was aimed at improving scientific predictions to ensure we are enhancing carbon outcomes with our recommended policies, "with attention paid to recommendations that would create offset projects that are real, permanent, quantifiable, verifiable, and enforceable, and otherwise pursuant to RCW 70A.65.170(2)" (DNR contract FP-93-103800). The need to ensure these conditions were met is driven by the core requirements for forest offsets in carbon markets. Forest Offset Protocols (FOP), regardless of the certifying entity require that credits are above a *Baseline* (what occurs now), are *Additional* (to what would have occurred without intervention); address *Leakage* (current actions occur elsewhere or cause the same emissions elsewhere) and are *Permanent* (at least 100 years).

Workflow and project organized are presented visually in Figures 1-4.

Responsive to SB 5126
(21):2(b-d)

Responsive to SB 5126
(21):2(a)

Responsive to SB 5126
(HWP) Assessment
(21):2(b), Sec (19) and
RCW 70A.45.090
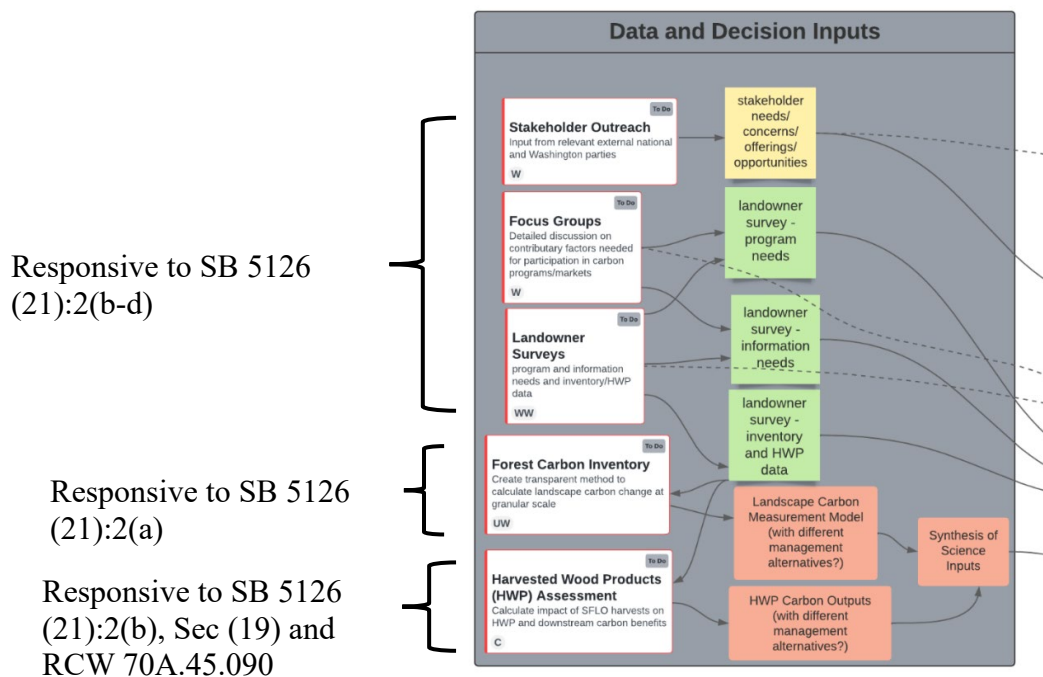
Figure 5: Small forest landowner carbon workgroup data and decision inputs

Responsive to SB 5126
(21):1
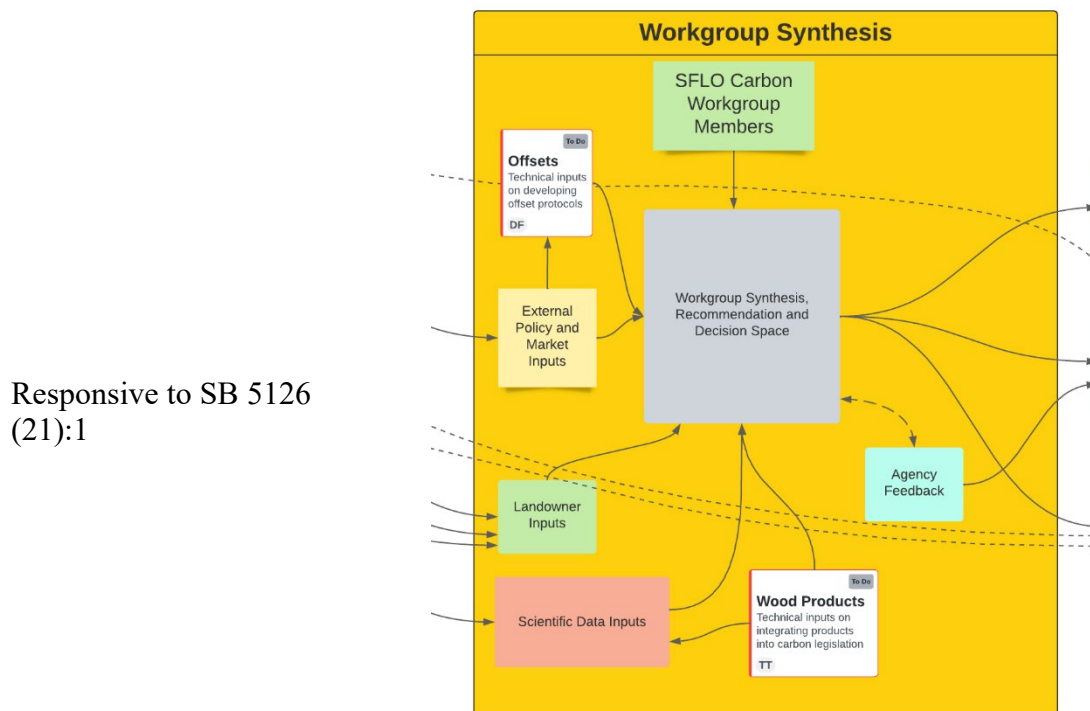
Figure 6: Small forest landowner carbon workgroup decision space

Data inputs, from the scientific studies, landowner surveys, and outreach (Figure 5) were synthesized and presented to the small forest landowner carbon workgroup (Figure 6), where workgroup members, including small forest landowners, technical experts in carbon protocols and carbon policy, agency leads, and subcontractors developed the recommendations herein for the legislature's consideration (Figure 7).

Driven by science

Driven by workgroup deliberations

Driven by SFLO needs
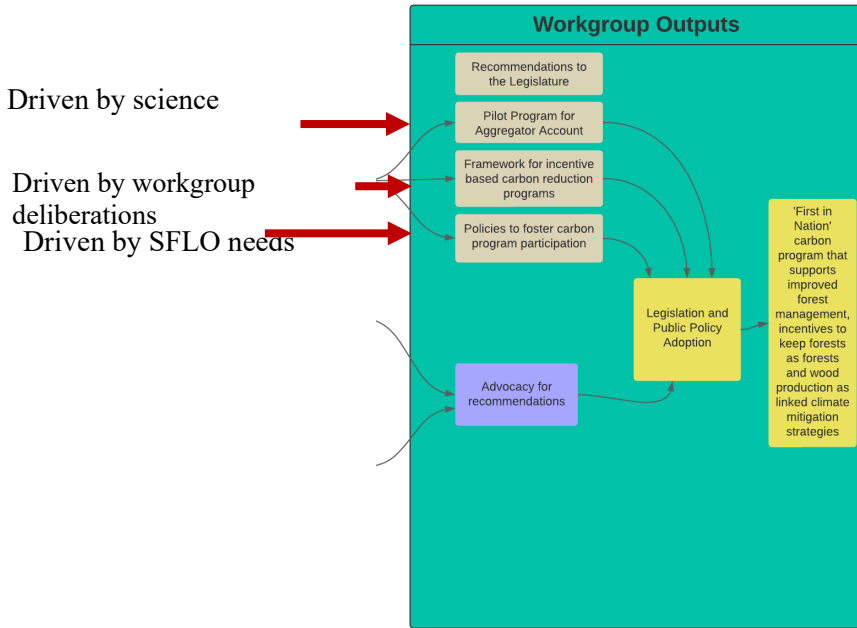
Figure 7: Workgroup recommendations to the legislature (June 2024)

Taken as the whole, the cross linkages between small forest landowner carbon workgroup elements (Figure 8) highlight the complex and integrated nature of this project.
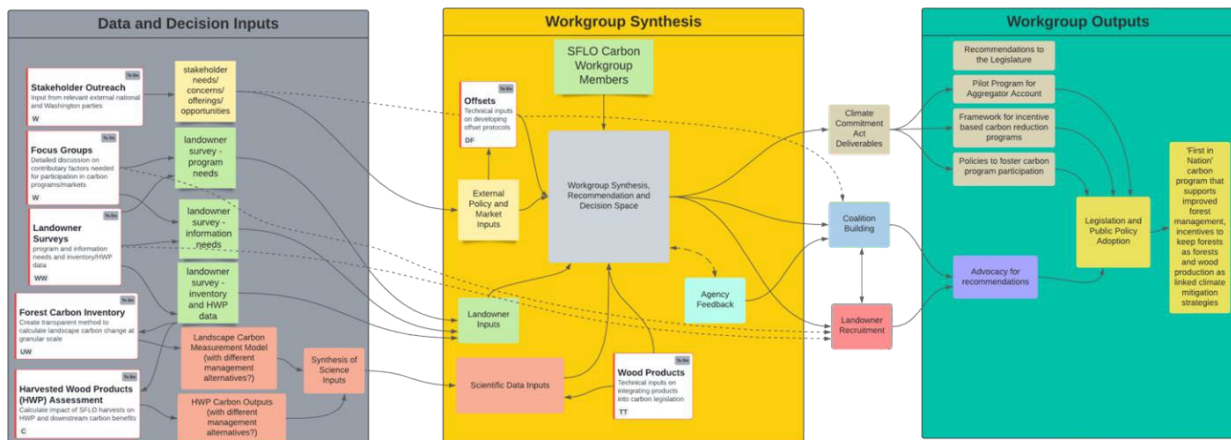
Figure 8 : Small forest landowner carbon workgroup integrated workflow

The roadmap developed for this project (*Figure 9*) organizes the complexity into its key components. These components were tackled individually, with findings integrated to derive policy and funding recommendations that are most likely to overcome barriers and support SFLO participation in emerging markets for natural climate solutions.
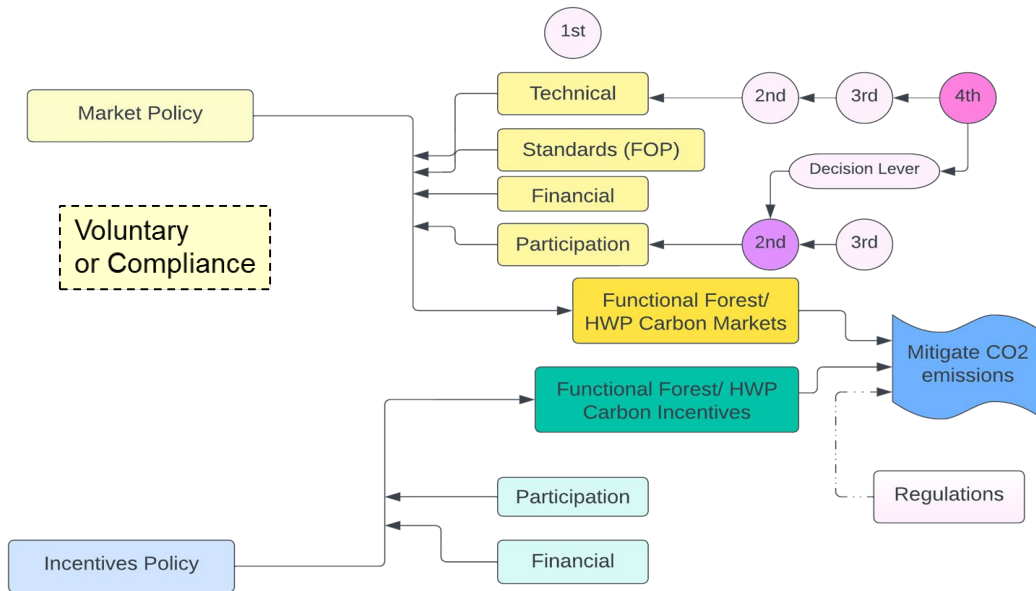
Figure 9: Small Forest Landowner Carbon Workgroup Road Map

Setting the Stage

Washington's forests

Washington's forests encompass 22 million acres, or nearly ½ of Washington's land base. Washington State is ranked #1 in the USA in terms of site productivity (Figure 10); a designation driven largely by the high-quality forest soils and long growing seasons found in western Washington.
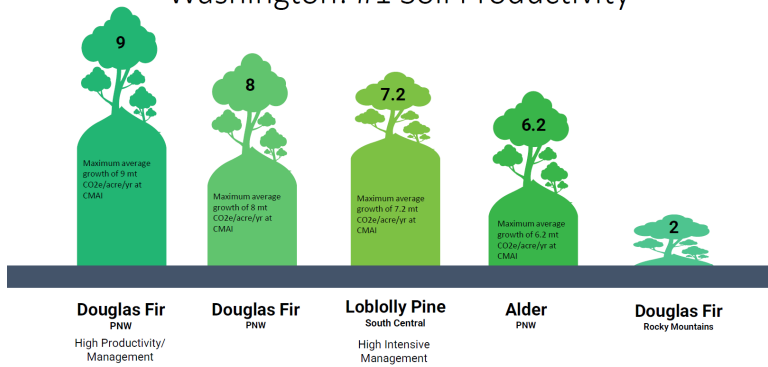
Figure 10: Washington Ranked #1 in Soil Productivity

Within these forests there are a wide range of species, ownership and management styles, disturbance risks, and carbon sequestration opportunities. For example, a map of the live aboveground and belowground forest carbon is provided in Figure 11. Statewide, Washington forests store 1.11 billion metric tons of carbon in live above ground and below ground components. Western Washington accounts for 78 percent (867 million metric tons) on 59% of the acres compared to 21.9 percent in Eastern Washington (246 million metric tons) on 41% of the forested acres.
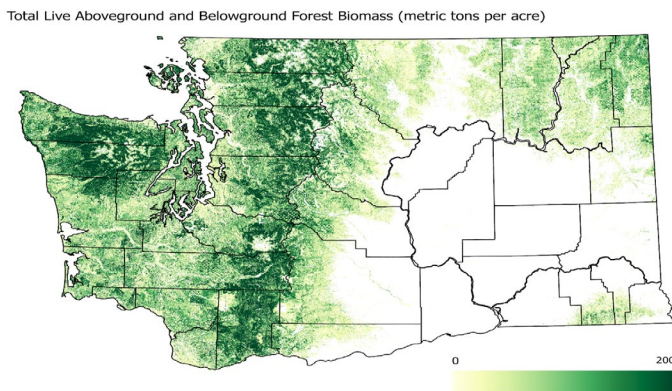
Figure 11: Map of total live aboveground and belowground forest biomass in Washington.

Small Forest Land Ownership and Allocation

The number and diversity of SFLO - in terms of acreage, goals, and expected tenure as landowners - presents significant challenges to proposing a carbon program that could work for some, most, or all SFLO in Washington State. The demographic and trend data informed our approach to identifying the needs and barriers that will drive recommendations for meeting the goals of Section 21 of the Climate Commitment Act.

In 2019, the Washington State legislature passed Senate Bill 5330 to fund an updated forest

landowner spatial database that could be used to assess trends in small forest landowner (SFLO) ownership, evaluate the impacts of the forests and fish law on small forest landowners, and determine what, if anything, could be done to address trends that were unfavorable for maintaining forest land ownership in this category of landowners. The 2021 UW report on Washington's small forest landowners[7] that came from that funding shows that small forest landowners own 15% of Washington's forest land, that acreage is nearly equally divided between eastern and western Washington (*Figure 12*) , and the forests are being converted to other uses at almost double the rate of the statewide average (*Table 5*).
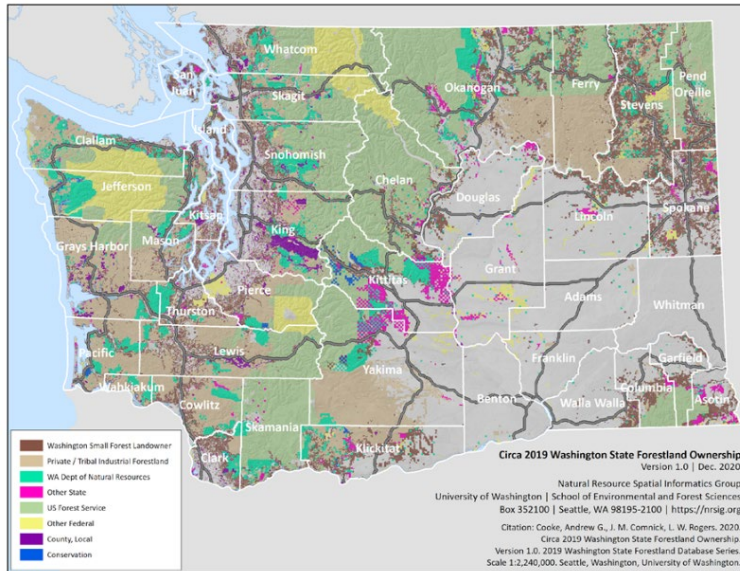
Figure 12: Family Forest Land Ownership in Washington State.

Table 5: SFLO Forest Land Conversion Rates.

	2007	2019	Change
Forest Acres (millions)	19.64	19.25	-2.0%
SFLO Parcel Acres (millions)	5.04	4.84	-4.1%
SFLO Forested Acres (millions)	2.99	2.88	-3.9%
SFLO (# owners)	201,000	218,000	8.5%
SFLO (# parcels)	256,500	261,800	2.1%

The conversion risk is concentrated in only a few areas of the state as shown in *Figure 13* with an additional 178,000 acres likely to convert by 2030 (UW 2021 Study).

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[7] Rabotyagov, et al, 2021, Washington's Small Forest Landowners in 2021
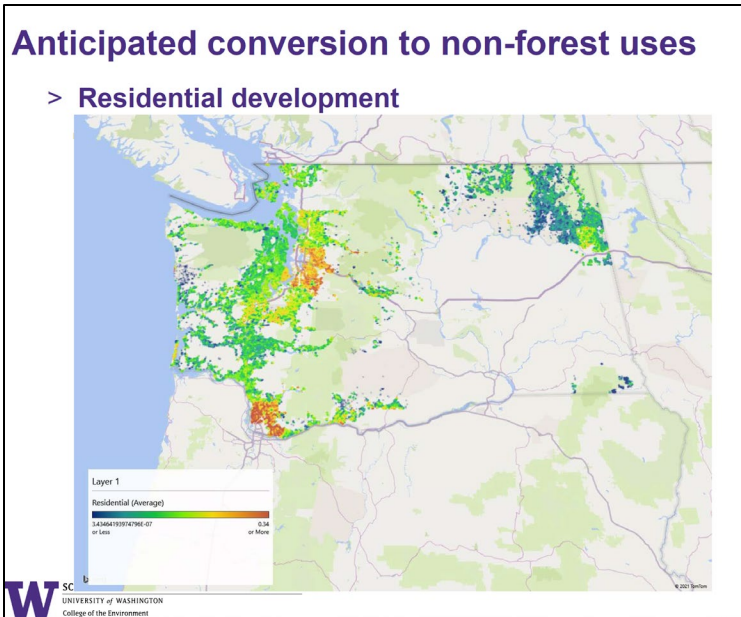
Figure 13: Expected conversion risk of forest land to non-forest land (2020-2030)

Small Forest Landowner Demographics

Major trends highlighted in the UW 2021 study include the following demographic trends that are relevant to this analysis (all *italicized* bullets directly from that report).

- *In 2007, there were 19.64 million acres of forest in Washington State. Forest acres declined by 394,000 acres (or 2%) by 2019.*

- *Small forest landowners (SFLO) account for 15% of forest acres. SFLO forest acres declined from 2.99 million acres in 2007 to 2.88 million acres in 2019 (a 3.7% decline). Total parcel acreage owned by SFLO declined from 5.04 million acres to 4.84 million acres (a 4% decline). The number of small forest landowners increased from 201,000 in 2007 to 218,000 in 2019 (or 8.5%). The number of SFLO parcels increased from 256,500 to 261,800 (or 2.1%).*

- *Seventy-seven percent of SFLO owned less than 20 acres in 2007 and accounted for 22% of forest acres. Small forest landowners who owned between 100 and 1000 acres accounted for the largest percent of forestland acreage (36%), followed by SFLO who owned between 20 and 100 acres (30%).*

- *Between 2007 and 2019, SFLO forest acres in the three smallest size classes (<20 acres, 20- 100 acres, 100-1000 acres) declined by 117,000 acres while the two largest size classes (1000-5000 acres, 5000+ acres) increased by 13,500 acres.*

- *The number of owners increased across all size classes, with the largest increase in the 20- 100 acres class (+9,700).*

- *Seventy-one percent of SFLO forest acres in 2007 were in the forestry or natural land use classes, followed by Residential (18%) and Agriculture (10%). By 2019, SFLO forest acres in forestry or natural land uses declined by 121,500 acres (or 5.7%) while Residential increased by 48,600 acres (or 9%).*

- *Parcels transitioned both out of and into the SFLO owner class. Between 2007 and 2019, approximately 450,000 acres (or 15%) left the SFLO class while 238,000 acres (an equivalent of 8% of 2007 area) transitioned into small forest landownership.*

- *Of the 67% of acres moving out of SFLO that remained forested, Private Industry (107,000 acres) was the largest destination owner class, followed by Private Other (60,000 acres), Tribal (50,000 acres), and Private Conservation (25,000 acres).*

- *The plurality of acres transitioning into SFLO were Private Industry in 2007 (92,000 acres).*

- *Somewhere between 25,000 and 50,000 small forest landowners are likely anticipating selling all or some of their forest land in the coming 10 years. Somewhat fewer than 1 in 10 current SFLOs have likely ever sold or given away some, but not all, of their forest land.*

- *The most important aspects of ownership for SFLOs, on average, are beauty and scenery, provision of wildlife habitat and environmental benefits, and privacy and personal attachment. "The protection of water resources" ranks highly as an ownership objective among Washington State SFLOs.*

- *SFLOs who have a sole focus on income and investment from their forests may constitute a minority of ownerships, but they tend to own disproportionately more of the state's Small Forest Land. Conversely, owners who tend to value their forest lands primarily for Family and Privacy purposes represent a substantial number of owners, but a very small amount of Small Forest Land. Many SFLOs who give low priority to timber harvesting still perform some kind of forest management in the course of their forest ownership.*

- *Consider a variety of alternatives the State can pursue to support carbon benefits on Small Forest Lands. Ultimately, the current high fixed costs for participating in a carbon offset program will likely exclude the vast majority of Washington State SFLOs from existing voluntary and compliance carbon offsetting programs for the time being. However, offset markets are only one way to pay SFLOs for the carbon value of their lands.*

Pathways to Engage Small Forest Landowners in Climate Smart Forestry

There are three pathways small family forest landowners can navigate to manage their forests in ways which will contribute to climate mitigation. Within the realm of natural climate solutions, forests offer the most practical and cost-effective pathway to remove and store large amounts of carbon in the forest and in long lived wood-based products.

The three pathways are participation in 1) a regulated forest carbon offset program, such as the Washington Cap and Invest program; 2) the voluntary forest carbon offset market, such as programs offered by ACR, VERRA, and the Climate Action Registry (CAR); or 3) incentive-based programs offered through federal and state agencies, such as Natural Resources Conservation Service (NRCS), state natural resource agencies, and non-profits such as the Family Forest Carbon Program – a joint program of American Forest Foundation and The Nature Conservancy.

Each of these pathways has benefits and risks to small forest landowners, as well as barriers to entry and impediments to participation due to programmatic requirements and time commitments. As a result of these challenges, Washington small forest landowners have not been actively involved in either regulated or voluntary forest carbon offset programs, and only a small percentage have taken advantage of available incentive-based programs.

Carbon Market Attributes

All carbon market protocols have four key elements: baseline, additionality, leakage, and permanence:

> **Baseline** – is a pre-defined business as usual scenario representing that which would have occurred had the carbon credit not been given. Credits are calculated based on differences in carbon stocks between baseline and project activities with deduction for secondary effects (leakage), project risk (buffer pool), and additions for harvested wood products. The baseline can be either static (eg for California and Washington Forest Offset Protocols (FOP) or dynamic (e.g. Family Forest Carbon Program).   Baseline is typically defined as Business as Usual (BAU) in the context of short-rotation timber production. It may be defined as average condition in your region/owner class/forest type or similar approaches. The challenge with baselines in the context of Washington's SFLO is that it encourages and rewards non-managers who have done a poor job of maintaining their forests while not crediting tree farmers for their prior good work improving their forests. It is particularly problematic in eastern Washington where a baseline for a fire resilient healthy forest could be 50-70% fewer trees than are currently on site.

> **Additionality** – refers to the idea that the carbon that is available to the market is additional to what would have occurred without it. Each carbon program has a different set of definitions of what is allowed or disallowed under the additionality clause of their methodology. Plus, they have deductions for expectations of market 'leakage' which is explained below. In some instances, to qualify as additional, the carbon accumulated has

to be above what is required by law. So, for example, the Forests and Fish law regulating buffer widths on nearly all of Washington's privately owned forest land would not count as 'additional' and any extra buffers required with proposed law changes would also be excluded from carbon market consideration due to the additionality test under most current carbon market programs. Entire reference documents have been written about how to measure it[8] which is indicative of the difficulties in measuring it in a way that is fair, equitable, and actually mitigates carbon emissions.

Leakage - Historically, leakage was defined as the "activity shifting leakage" that occurs when harvesting shifts elsewhere within the same land ownership as the carbon project itself. In those cases, carbon gains in one area under the landowner's management, are negated by increased harvest and carbon losses elsewhere in the same landscape. This approach considers only the forest as providing the overall climate mitigation benefit, and not the forest, plus product, plus substitution, benefit as has been developed for the CWG project.

"Market shifting leakage" is where an intervention may reduce wood supply in one region, but the aggregate market demand and supply are not reduced. Market shifting may occur within a region, state or country. It speaks directly to the product element, but not the potential for market shifting away from wood products to alternatives, which is more accurately captured by quantifying the substitution benefits of the product stream. In both cases there is a carbon mitigation impact, though traditionally carbon markets have dealt only with wood harvest moving elsewhere, rather than a move away from wood products into alternative products that (usually) have a higher carbon footprint.

The productivity of Washington's forests combined with their global importance as a wood supplier means that we can expect market shifting if there is substantial reduction in Washington's wood supply from carbon market programs. Given the requirement of state law under RCW 70A.45.090-100 regarding the forest and forest products sector carbon sequestration potential of the state, any intervention that reduces wood supply will not only result in market leakage but will be contrary to the intent of current state law. Surveys show that not all SFLO plan to harvest, so this requirement to account for leakage will impact only those lands that are classified as designated forest lands (DFL), a status that requires periodic harvest in lieu of annual tax payments.

Permanence is described as a requirement that the carbon remain in a stock (i.e. out of the atmosphere) for an extended time frame, usually 30–100 years. Each protocol has a different time frame and a system for accounting for reversals, either unintentional (e.g. wildfire) or intentional (harvest of a stand reserved from harvest). Permanence is built into contractual obligations in short and long-term agreements/ easements and may be compensated on a pro-rata basis for the duration of services delivered. In many instances some of the carbon generated goes into a 'buffer pool' to guard against the risk of reversal. One would expect that in a fire dominated system like eastern Washington, the buffer pool would be quite large to compensate for potential losses.

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[8] [Additionality Definitions From the World Bank](#)

These attributes all play a role in the following descriptions of available regulated and voluntary carbon programs.

Regulated Programs

There are two regulated forest offset programs available for use by Washington forest landowners – the Washington Cap and Invest program and the California Air Resources Board (CARB) program.

The Washington Department of Ecology adopted its Forest Offset Protocol as part of the broader Climate Commitment Act Program Rule on September 29, 2022. The Washington Forest Offset Protocol mirrors the most current version of California's Forest Offset Protocol adopted June 25, 2015.

California first adopted its Forest Offset Protocol on October 20, 2011. This protocol was part of the state's efforts to integrate forest conservation and management practices into its greenhouse gas reduction strategy under its cap-and-trade program. The California Forest Offset Protocol has been updated twice since its introduction, with the current version adopted in 2015.

To date, no Washington private small forest landowners have participated in either the Washington or California Forest Offset Protocol, although the CARB program has been available since its first forest offset protocol was adopted in 2011. This is due to barriers to entry and impediments to participation, which are summarized below.

Washington's Forest Offset Protocol

The Washington Department of Ecology's Forest Offset Protocol, established as part of the state's cap-and-invest program, is designed to incorporate forest management projects that contribute to carbon removal and storage efforts. This protocol is aligned with Washington's broader climate goals of reducing greenhouse gas emissions and promoting sustainable land management. The protocol enables forest landowners to generate offset credits by maintaining or enhancing forest carbon stocks, which can then be used to meet compliance obligations under the state's emission reduction regulations. Such measures also support a range of co-benefits, such as clean water, wildlife and fish habitat, biodiversity, and enhancing the resilience of forest ecosystems.

Under this protocol, three project types are allowed - reforestation, improved forest management, and avoided conversion projects. Reforestation projects focus on planting trees in deforested or degraded lands, thereby increasing carbon removal and storage capacity. Improved forest management practices involve modifications to forest harvesting techniques and rotation lengths to increase carbon removal and long-term storage. Avoided conversion projects protect forests that are at risk of being cleared for alternative uses, thus maintaining their carbon removal and storage capabilities. Each project type must adhere to specific eligibility criteria and performance benchmarks to ensure carbon credits are real, measurable, permanent, and additional carbon reductions.

The Washington Cap and Invest program, as part of the state's Climate Commitment Act, authorized two carbon registries for listing and verification of offset projects. These are ACR and the Climate Action Reserve (CAR). This system allows project developers to register and verify their projects under these recognized platforms, facilitating the generation of offset credits that can be used within Washington's carbon market to meet regulatory requirements or for voluntary purposes.

Barriers and Impediments to Small Forest Landowner Participation

There are numerous barriers and impediments small forest landowners must overcome to participate in the regulated forest carbon offset market. These include:

9. **High Initial Costs**: The upfront costs associated with developing and verifying a forest offset project can be prohibitive for small forest landowners. These costs include the expenses of measuring and monitoring carbon stocks, preparing project documentation, and undergoing third-party verification.

10. **Complexity of Protocol**: The protocol for forest carbon offset projects is complex and technical. Understanding and navigating these requirements can be challenging for small forest landowners who may not have the resources or expertise to manage the rigorous demands of project development, verification, and ongoing compliance.

11. **Economies of Scale**: Carbon offset projects typically achieve greater financial viability with scale due to lower per-unit costs. Small forest parcels may not independently meet the minimum acreage requirements to generate sufficient carbon credits to attract buyers, making it less economically feasible for small forest landowners to participate without aggregating their lands with others, which is impractical for multigenerational commitments.

12. **Long-term Commitment**: Carbon offset projects require a long-term commitment to specific land management practices to ensure the permanence of carbon sequestration. In the case of the Washington Forest Offset Protocol, the initial crediting period is 25 years, with the requirement to maintain carbon stocks for 100 years after the end of the crediting period (minimum 125 years). This long duration is a significant deterrent for small forest landowners who need flexibility in their land management for economic or personal reasons.

13. **Restrictions of Forest Management Practices**: Restrictions on forest management practices contained in the Washington Forest Offset Protocol (FOP) are not practical for managing forest types found across Washington, such as Douglas-fir and hemlock forests. In addition, prescriptive forest management requirements contained in the Washington FOP are not consistent with the Washington Forest Practices Act requirements. Examples include:
    - even-aged harvest units may be no larger than 40 acres
    - limits on the percentage of a single species of live trees within a project area based on a prescribed species diversity index by assessment area
    - limits on age class distribution within watersheds
    - prescriptive standing and dead wood requirements

- all forest parcels owned by a project participant must be third-party certified to the American Tree Farm program, Forest Stewardship Council, or the Sustainable Forestry Initiative

14. **Market Accessibility**: The market for carbon credits can be opaque and difficult to access for smaller producers. Without the knowledge or connections to find and negotiate with buyers, small forest landowners may find it challenging to sell their carbon credits at fair prices.

15. **Regulatory and Administrative Burdens**: The administrative burden of participating in carbon markets, including ongoing monitoring and reporting requirements, can be significant. For small forest landowners who typically do not have dedicated staff for such activities, these demands can be overwhelming.

16. **Lack of Tailored Support and Resources**: There is often a lack of targeted support, resources, and incentives for small forest landowners to participate in carbon markets. This includes technical assistance, financial incentives to offset initial costs, and guidance through the regulatory landscape.

For a summary of specific requirements of the Washington Forest Offset Protocol, see Appendix 3.

Voluntary Programs

Multiple voluntary carbon programs are available to small forest landowners in Washinton which offer a pathway to additional income through carbon credits, while incentivizing sustainable forest management practices that enhance forest health, productivity, biodiversity, improve water quality, and combat climate change.

To participate in the voluntary carbon market, small forest landowners need assistance to understand the options available through registries, carbon standards, and forestry methodologies in Washington. However, like the Washington regulated carbon offset program, small forest landowners face many barriers and impediments to participating in voluntary carbon programs.

Registries

Carbon offset registries serve as platforms where carbon credits can be registered, verified, tracked, traded, and retired. They ensure the integrity and transparency of carbon offset projects by enforcing adherence to established standards and methodologies. For small forest landowners, the following registries are particularly relevant:

Verra[9] - previously known as the Verified Carbon Standard, Verra is the most widely used carbon offset registries globally. It offers the Verified Carbon Standard (VCS) for quantifying and verifying carbon credits from forestry and other land use projects. It offers a standard, methodologies, and verification requirements. Under VCS, the registry offers several forestry

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[9] Home | Verra

methodologies for use in the U.S. including for Improved Forest Management (VM0003, VM0045), reforestation (VM0047), and biochar (VM0044) as detailed in Appendix 3.

ACR[10] **–** previously known as the American Carbon Registry, ACR established the first carbon registry in 1996 and its improved forest management methodology is the most widely used in the U.S. and in Washington. ACR maintains a standard, methodologies, and verification criteria for carbon offset projects, [11] for Improved Forest Management, reforestation, and forest conservation.

Climate Action Reserve (CAR) – previously known as the California Climate Action Registry and created by the State of California in 2001, CAR became a non-profit in 2008. CAR operates a registry, maintains a standard, methodologies, and verification requirements. CAR offers a U.S. Forest Offset Protocol that includes improved forest management, reforestation, and avoided conversion project types. The current California and Washington regulated FOP were developed from the CAR voluntary FOP. CAR also offers a b[12] reforestation program.

Registry Standards

Registry Standards guide the creation, verification, and monitoring of carbon offset projects, ensuring they deliver real, measurable, permanent, and additional carbon reductions. They define how projects should be designed and operated to produce valid credits.

Methodologies

Methodologies are specific procedures or approaches prescribed by standards for quantifying the carbon removed or emissions avoided by a project. They are critical in ensuring the consistency and accuracy of the carbon credits generated. For forestry projects, methodologies detail procedures for measuring the carbon stocks in forests and for monitoring changes over time. Examples include: ACR's *Improved Forest Management (IFM) on Non-Federal U.S. Forestlands*[13] and VERRA's *Methodology for Improved Forest Management through Extension of Rotation Age* (VM0003)[14].

Barriers and Impediments to Small Forest Landowner Participation

There are numerous barriers and impediments small forest landowners must overcome to participate in the voluntary forest carbon offset market. These include:

1. **High Initial Costs**: The upfront costs associated with developing and verifying a forest offset project can be prohibitive for small forest landowners. These costs include the expenses of measuring and monitoring carbon stocks, preparing project documentation, and undergoing third-party verification.
2. **Complexity of Protocol**: The protocol for forest carbon offset projects is complex and technical. Understanding and navigating these requirements can be challenging for small

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[10] Registry - ACR (acrcarbon.org)
[11] Methodologies - ACR (acrcarbon.org)
[12] Climate Forward – Accelerating Action on Climate Change
[13] Improved Forest Management (IFM) on Non-Federal U.S. Forestlands - ACR (acrcarbon.org)
[14] VM0003 Methodology for Improved Forest Management through Extension of Rotation Age, v1.3 - Verra

forest landowners who may not have the resources or expertise to manage the rigorous demands of project development, verification, and ongoing compliance.

3. **Economies of Scale**: Carbon offset projects typically achieve greater financial viability with scale due to lower per-unit costs. Small forest parcels may not independently meet the minimum acreage requirements to generate sufficient carbon credits to attract buyers, making it less economically feasible for small forest landowners to participate without aggregating their lands with others, which is possible under several voluntary methodologies.

4. **Market Accessibility**: The market for carbon credits can be opaque and difficult to access for smaller producers. Without the knowledge or connections to find and negotiate with buyers, small forest landowners may find it challenging to sell their carbon credits at fair prices.

5. **Administrative Burdens**: The administrative burden of participating in carbon markets, including ongoing monitoring and reporting requirements, can be significant. For small forest landowners who typically do not have dedicated staff for such activities, these demands can be overwhelming.

6. **Lack of Tailored Support and Resources**: There is often a lack of targeted support, resources, and incentives for small forest landowners to participate in carbon markets. This includes technical assistance, financial incentives to offset initial costs, and guidance through the regulatory landscape.

7. **Lack of Labor**: One of the challenges for an aging community of SFLO, especially those without heirs, is a lack of labor. Even if these landowners had $ from a carbon program, many of them would not be able to perform the work themselves. Additionally, landowners report a general shortage of labor to do the work of forestry.

For a summary of specific requirements of the ACR Improved Forest Management methodology, see Appendix 3.

Incentive Programs

In Washington, there are approximately 218,000 small forest landowners[15]. These landowners collectively own about 2.9 million acres of forestland, which represents about half of the private forestland in the state. These landowners have the potential to significantly contribute to removing and storing additional carbon through climate smart forestry practices. However, most of these landowners are unlikely to participate in a regulated or voluntary carbon program due to the barriers to entry and impediments to operating a carbon offset project. Thus, offering incentives to small forest landowners is an important pathway to encourage voluntary implementation forest practices that will increase carbon removal and storage on their land and in wood-based products produced from sustainable harvesting over time.

The Washington Legislature and state agencies (Department of Ecology and Natural Resources) should fund:

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[15] Small Forest Landowner Office | WA - DNR

Financial incentives for small forest landowner participation in carbon markets

- Offer loan or bond guarantees to reduce the cost of capital financing of forest carbon projects that require patient capital recovery, including reforestation, fire risk reduction, and improved forest management. Qualified forest carbon projects would be required to use a methodology approved by a credible, third-party entity, as determined by the Department of Ecology.
- Offer grants to small forest landowners that will assist in covering a portion of the upfront costs of developing a forest carbon project, such as the cost of a carbon inventory and third-party verification.

These incentives should ensure participation of historically underserved small forest landowners while balancing the need for achieving scale.

The Washington Legislature and state agencies (Department of Ecology and Natural Resources) should authorize and implement:

Carbon market insurance or a buffer pool to incentivize small forest landowner participation in carbon programs

- Create a state insurance product or a state buffer pool for use by the private carbon marketplace as an alternative to depositing a portion of project carbon credits into a registry buffer pool account.

Currently, forest carbon market projects undergo a risk buffer analysis to address leakage and reversals. Landowners must either contribute a certain percentage of project carbon credits to a registry buffer pool or buy insurance. Presently, no insurance product is available to act as a substitute for banking credits. A state backed insurance product or buffer pool of credits from third-party approved forest projects could be used by forest carbon project owners to meet, in part or in full, carbon registry buffer pool obligations to protect against losses caused by reversals and to ensure that all issued carbon credits are permanent. This is intended to reduce costs and incentivize small forest landowner participation in forest carbon projects.

The Washington Legislature and state agencies (Department of Ecology and Natural Resources) should fund:

Technical Assistance to support small forest landowners in voluntary actions to remove and store carbon

- Education and Training – a key barrier to participation in carbon offset programs and voluntary actions to implement forest practices that will increase carbon removal and storage on their land is the lack of knowledge and information about these opportunities.
The Washington Legislature should direct funding to the Washington Department of Natural Resources with a directive to issue a block grant to WFFA, a Washington non-profit operated under the direction of small forest landowners for the purpose of developing and implementing an education and training program for small forest landowners on carbon offset programs and to build capacity to assist landowners in accessing financial, technical, and implementation support.

A block grant is a type of funding issued from a government to a local or state organization for general purposes, allowing the recipient more discretion over how the funds are used. The concept behind block grants is to provide more efficiency in the use of funds and foster innovative solutions to problems at the local level.

<u>Incentive payments to implement carbon smart forestry practices</u>

The Family Forest Carbon Program[16] is a pathway for small family forest landowners to improve forest health and help mitigate climate change while earning an income to cover the cost of taking care of their land. The program helps landowners implement improved forestry practices in their forests that result in greater amounts of carbon removed and stored in their trees. Companies and other organizations can purchase verified carbon credits generated from the additional carbon removed and stored on woodlands enrolled in the program.

Upon enrollment, landowners receive payments for implementing forest management practices that increase the carbon removed and stored on their land. They also receive an expert consultation from a forester and a forest management plan uniquely designed for their property and goals. Basic eligibility requires a landowner have forested property in a region currently covered by the Family Forest Carbon Program, own 30 or more acres of native trees on their property, have the legal right to harvest on the property and be able to commit to a 20-year agreement.

The program's main goal is to connect landowners with forestry professionals to assist in the stewardship of their forestland. The Family Forest Carbon Program is perfect for landowners who are trying to manage their forestland to promote the growth of native species, create older and more mature forests, and improve wildlife and fish habitat.

The program was developed by two national nonprofits, the American Forest Foundation and The Nature Conservancy, to help landowners implement sustainable forest management practices that result in healthier forests, higher-quality timber, improved wildlife habitat and increased carbon removal and storage. The Program is operated by the Family Forest Impact Foundation, an affiliate of the American Forest Foundation.

Currently, the Family Forest Carbon Program is not operating in any western state. However, the program is looking to expand into the west and is seeking on-the-ground partners to operate the program, akin to a franchise arrangement. WFFA is in discussions with the Family Forest Carbon Program about being its on-the-ground partner in Washington.

Prior to launching the Family Forest Carbon Program in Washington, a set of forest practices must be identified that will increase carbon removal and storage on small forest parcels, so increases in carbon can be measured, and payment rates can be established. This requires plot data, either measured on-the-ground or remotely, to determine existing stocks and measure carbon stock changes over time. The work recently completed to measure carbon stock changes

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[16] How It Works | Family Forest Carbon Program

over time by University of Washington's NRSIG as part of this Washington DNR contract now makes it possible to fulfill the data needs necessary to operate the Family Forest Carbon Program.

The Washington State Legislature should provide seed funding in the form of a block grant through the Washington Department of Natural Resources to WFFA, a Washington non-profit operated under the direction of small family forest landowners for the purpose of setting up a franchise of the Family Forest Carbon Program in Washington.

FFCP PNW Partnership Requirements

Like other states, if Washington is to become a part of the FFCP family of participating states, we will need to develop the core carbon team here in the region. Preliminary discussions with the FFCP indicate that there are plenty of ways to engage with them, starting with a well-developed MOU that establishes clear targets, task allocation between entities, financial obligations and expectations, and arms-length relationship standards. In other words, FFCP will not set up a program here without a dedicated entity that is fully resourced and able to commit to at least a 5-year effort to establish a viable regional program. Therefore, it is clear that we will need to establish an independent entity that can serve as the clearing house for the many elements needed to ensure SFLO have access to carbon markets, carbon incentives, and the support they need to participate in their chosen program.

One option is to develop a public/private partnership that can coordinate and magnify the efforts of the many organizations that see benefit, and will contribute, to bringing a carbon program into reality.
The Partnership would initially be tasked with three key tasks:
1) Development of SFLO specific protocols and eligible pathways to attain carbon benefit, including benefits for our fire dependent ecosystems.
   a. Based on outcomes of the NRSIG Tool
   b. Linked to the HWP accounting protocol required by RCW 70A.45.090
2) Close coordination with UW NRSIG who will provide ongoing updates and maintenance of remote sensing technology (research & development) to permit aggregation at a resolution that addresses protocol needs.
3) Maintenance of Project Registry for WA State (with opportunities to expand to the west coast)
4) Creation of partnerships and funding mechanisms to ensure the program becomes self-sustaining.

Building a Washington Specific Carbon Program – the Science

A specific deliverable identified in the CCA was to provide recommendations for the implementation and funding of a pilot program to develop an aggregator account that could pursue carbon offset projects for small forestland owners in Washington State, including recommendations based on programs established in other jurisdictions. Currently, there are limited carbon programs in Washington or other jurisdictions that are specific to small forest landowners. The most well-established program is the American Forest Foundation's (AFF) Family Forest Carbon Program (FFCP) which has recently expanded from 3 states to 15 states along the eastern seaboard of the USA.

Developing a Washington specific toolset for the aggregator account

The FFCP approach addresses aggregation by implementing the program at a landscape level, which reduces costs for landowners. Landowners adopt practices that are expected to increase carbon sequestration, and the carbon benefits are remotely monitored by comparing parcels entered into the program to comparable parcels in the landscape that are not enrolled. This comparison demonstrates the specific additionally created by the adoption of the practices and enrollment in the carbon program. The FFCP has worked with Verra, an internationally accepted carbon standards organization to develop a protocol for 'improved forest management' (VM00045) (Shoch et al. 2022), that compares the carbon accumulated on enrolled lands against matched forest inventory plots from programs such as the US Forest Service Forest Inventory and Analysis (FIA) program (McRoberts et al. 2005). At the outset we expected that the Verra VM00045 protocol could not be adopted in its current form for Washington state, or indeed anywhere in the western USA due to the strict matching requirements for the plots and the dearth of such matches here in the west. Alternatively, to participate in these programs, project carbon must be quantified using new field plots. The cost of installing these plots has been prohibitively expensive for small forest landowners (SFLO). There had to be a better way. We proposed an alternative method as part of the effort undertaken for the CWG project.

Our thought was that newly available datasets including digital aerial photogrammetry (DAP) from the National Agricultural Imagery Program (NAIP) meant it may be possible to replace field plots with remotely sensed forest inventory ("National Agriculture Imagery Program - NAIP Hub Site" 2023). This approach would rely on developing wall-to-wall predictions of forest composition and structure by developing statistical models from physical, climate, spectral, and photogrammetric datasets along with geolocated field plots.

We are happy to report that in this project, the University of Washington's Natural Resource Spatial Infomatics Group (hereafter NRSIG) were able to crack the code on integrating these disparate datasets to generate improved remotely sensed biomass and carbon estimates for all forested acres in Washington. This is the first successful effort of its kind in the nation, though

many other shops are endeavoring to do the same thing. Full details are in Appendix 1.

In brief, NRSIG were tasked with investigating the potential to use remotely sensed forest inventory for a carbon program. First, they developed a comprehensive database of forest inventory field plots from the Washington Department of Natural Resources (DNR) and the US Forest Service (USFS). For each plot, tree records were summarized to calculate species proportion and structure attributes on a per acre basis, including forest biomass and digital elevation models, climate layers, satellite imagery, and NAIP-derived DAP were processed. Next field plots were attributed with over 300 predictor variables. Models were developed to predict each response variable and produced statewide rasters at 66-foot resolution (1/10th acre). Accuracies of these models were reported at two spatial scales.

Second, the new prediction rasters and parcels from the Forestland Database were used to develop improved estimates of SFLO forest attributes (Rogers, Cooke, and Comnick 2023 - see Appendix 1). We summarized carbon in SFLO forests and compared the estimates from FIA. We contrasted the average forest structure attributes for SFLO against other major owner classes. We classified SFLO forest acres for several species, density, and size classes to identify opportunities for improved forest management.

Third, the models were applied in a demonstration tool for a theoretical forest carbon program. We selected the Verra improved forest management protocol to demonstrate how the program could work. While there are other standards and protocols for greenhouse gas reduction and offset projects, recent updates to the Verra protocol by the Family Forest Carbon Program (FFCP) were identified by the CWG as a promising starting point for Washington State small forest landowner engagement in carbon cap-and-trade markets. The Verra program compares actual growth and harvest activities for a project against matched plots over time. Here, we simulated treatments for the project and baseline plots using the Forest Vegetation Simulator (Crookston and Dixon 2005).

These efforts have created a quantum leap forward for carbon accounting, but more work is needed to bring them to market readiness. The outstanding issues and needs are identified in the recommendation section of this report to address this deliverable.

Testing the Tool to Estimate Forest Landowner Carbon Stocks

Using the NRSIG carbon tool (hereafter dubbed the Forest Genie by the CWG) the following forest landowner carbon stock estimates were generated. From the spatially explicit forest landowner database we can calculate that SFLO's own 1.15 (± 0.13) million acres of forestland in western Washington and 1.40 (± 0.16) million acres in eastern Washington. There are several different datasets and methods to estimate forest carbon stocks on these lands. The latest available data from the Forest Genie generated from this project show the variability between owner types, half-state (east vs west), and component (living biomass, dead biomass and soil) in Table 6 as compared to estimates derived from FIA sampling (1 plot per 6000 acres) in Table 7. The acreage cutoffs are somewhat different between the two datasets (i.e. what is classified as a

forest), but overall the two estimate procedures are in close agreement. This is significant because it opens the door for us to move forward with Forest Genie improvements so that remotely sensed carbon estimates can be included in forest offset protocols and standards as a viable measurement method.

Table 6. Summary of live aboveground and belowground carbon for SFLO forests in Washington using prediction rasters and the Forestland Database.

Owner Class	West			East		
	Forest Acres	Metric Tons Per Acre C	Total Metric Tons C	Forest Acres	Metric Tons Per Acre C	Total Metric Tons C
SFLO	1,423,714	53.5	76,911,725	1,460,819	21.3	31,935,417
Private Industrial	3,419,852	45.7	151,678,611	835,933	22.2	17,698,731
Tribal	357,882	47.1	17,931,111	1,068,252	22.1	30,214,059
DNR	1,269,914	79.0	108,110,245	514,803	27.8	16,337,915
Forest Service	3,137,029	107.9	369,048,703	3,701,111	38.2	159,878,816
Summary	11,739,608	73.9	867,318,306	8,036,122	30.7	246,330,750

Table 7. Summary of live aboveground and belowground carbon for SFLO forests using FIA and the Forestland Database.

Owner Class	West			East		
	Forest Acres	Metric Tons Per Acre C	Total Metric Tons C	Forest Acres	Metric Tons Per Acre C	Total Metric Tons C
SFLO	1,150,000	50.59	58,100,000	1,400,000	20.33	28,400,000

Ten percent of forest carbon is stored by SFLO (109 million metric tons). On average, SFLO forests store 37.7 metric tons of carbon per acre. SFLO store less carbon per acre than other owner types in eastern Washington and more carbon per acre in western WA compared to other private enterprises but less than public lands.

If we add in the non-living components of the forest land (soils, dead wood, etc) forests owned by Small Forest Landowners (SFLO) in Washington state store 223 million metric tons (MMT) of carbon *Table 8* . This represents 9.6% of the total carbon stored in Washington forests on 15% of the forested acres. On a per acres basis, SFLO forests store 87.5 metric tons per acre compared to an average value of 105.4 metric tons for all Washington forests. *Figure 14* shows these relationships graphically.

Table 8.Total and average per acre forest carbon for SFLO and all forest in Washington state by pool (95% confidence intervals are listed in parentheses).

	Total Forest Carbon (MMT)		Forest Carbon Per Acre (Metric Tons)	
Pool	SFLO	All Forests	SFLO	All Forests
Aboveground live	71.2 (± 6.92)	841.4 (± 16.5)	28.0 (± 2.12)	38.1 (± 0.73)
Belowground live	15.3 (± 1.51)	185.7 (± 3.7)	6.0 (± 0.47)	8.4 (± 0.16)
Dead wood	22.4 (± 1.89)	261.7 (± 4.0)	8.8 (± 0.48)	11.9 (± 0.16)
Litter	24.9 (± 2.07)	273.7 (± 3.6)	9.8 (± 0.40)	12.4 (± 0.12)
Soil organic	88.8 (± 6.54)	762.4 (± 8.9)	34.9 (± 0.87)	34.6 (± 0.25)
Total	222.6 (± 17.1)	2324.8 (± 30.4)	87.5 (± 3.46)	105.4 (± 1.15)

Figure 14. Area, total carbon, and average carbon per acre by pool for each owner class in Washington state. The SFLO owner class is highlighted. (St-Ot = State Other, St-DNR = Washington Department of Natural Resources, Pvt/Trb-Ind = Private or Tribal Industrial, Pvt-SFLO = Small Forest Landowner, Pvt-Ot = Private Other, Fed-Ot = Federal Other, Fed-FS = USDA Forest Service)

Incorporating Forest Harvest into the Carbon Calculus

The primary commercially harvested species in the PNW, Douglas fir, is a critical component of US wood supply. Washington ranks 3rd (behind Oregon and Georgia) in US sawtimber production, which accounts for 19% of global sawtimber production. Harvest has declined from a high of nearly 6 billion board feet (BBF) in the 1980s to a current level of about 2.5 BBF annually (Figure 15). In a typical year anywhere from 9-12% of harvest volume comes from SFLO lands.[17]

Section 21 and its cross references dictated that the CWG project strive to articulate actionable approaches to meeting the aspirational goals of RCW 70A.45.090. Though complex, it has been

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[17] Palmer, Marin; Kuegler, Olaf; Christensen, Glenn, tech. eds. 2018. Washington's forest resources, 2007–2016: Ten Year Forest Inventory and Analysis report. Gen. Tech. Rep. PNW-GTR-976. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 75 p.

an exciting opportunity to provide a tangible example to the rest of the world on how to implement regional policies to meet global goals as outlined the latest United Nations Climate Change Conference (COP 27) Report on *The Growing Role of Forest Products in Climate Change Mitigation*. Integrating the forest and wood product outputs into tradeable carbon credit schemes has been identified in other carbon projects, including the Family Forest Carbon Program. However, the estimation procedures are complex, generalized, and most certainly do not have any granularity to them that would provide credit for forest management that creates higher value or more long-lived products than the norm.

Given the requirement to integrate the findings of RCW 70A.45.090 into our recommendations on offsets (RCW 70A.65.170), it was necessary to aggregate data on timber harvest from Washington DNR harvest databases (Figure 15). Those databases show that private non-corporate interests provide a substantial, though declining, proportion of the timber harvest used by our local milling infrastructure. The peak of SFLO and Tribal harvest in 2007 corresponded with a building boom and very high prices for logs, making even the smallest properties and lowest quality wood commercially accessible. If those properties were successfully reforested as required by law, then we should see a substantial number of acres of 15-year-old forests in our datasets. That may not be the case as UW NRSIG 2021 study found that conversion to non-forest uses (housing, development, agriculture) is more likely after harvest. The 2008 economic collapse that followed was a period of very low prices and subsequently depressed harvest rates for small forest landowners, but not as low as for other landowner types with presumably more patient capital.
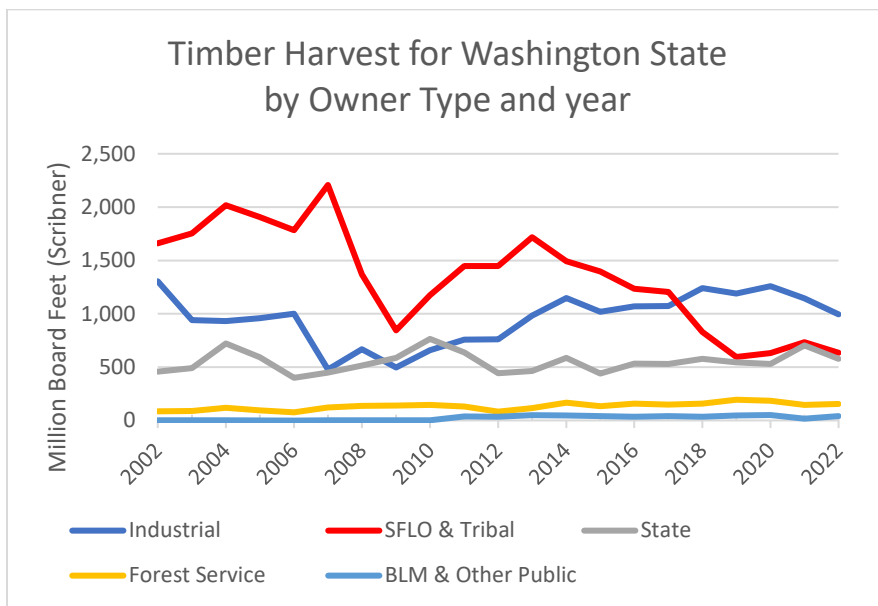
Figure 15: Washington Timber Harvest by Owner Type and Year

Developing Harvested Wood Product Estimates

Most harvested logs are processed at sawmills into lumber (*Figure 16*) and most harvest volume comes from western Washington (*Figure 17*)[18]. We used these broad general harvest trends to focus our assessment on the most likely pathways for wood harvested from SFLO lands to enter the manufacturing stream, and its ultimate carbon footprint over time. The carbon analysis for harvested wood products (HWP) utilizes life cycle assessment (LCA) consistent with internationally recognized protocols for carbon accounting of HWP. A full report of the findings is provided in Appendix 2.

In brief, data were developed to represent the expected distribution and harvest recovery across regionally variable forest types and management scenarios generated by the Forest Genie analysis. This resulted in 12 different management/manufacturing scenarios with a range of embodied carbon as shown in *Figure 18*. Embodied carbon is the amount of carbon emitted per unit of product – in this case a m3 of sawn lumber. Since wood is approximately 50% carbon by dry weight, each m3 of HWP also stores carbon. This stored carbon is calculated based on product density and species. The difference between embodied carbon and stored carbon is the net carbon impact of producing that product as shown in *Figure 19*. As is the case with nearly all wood products, they store more carbon than is emitted in their production including emissions associated with growth, harvesting, hauling and manufacturing as shown here.

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[18] https://www.fs.usda.gov/research/products/dataandtools/tools/timber-products-output-tpo-interactive-reporting-tool
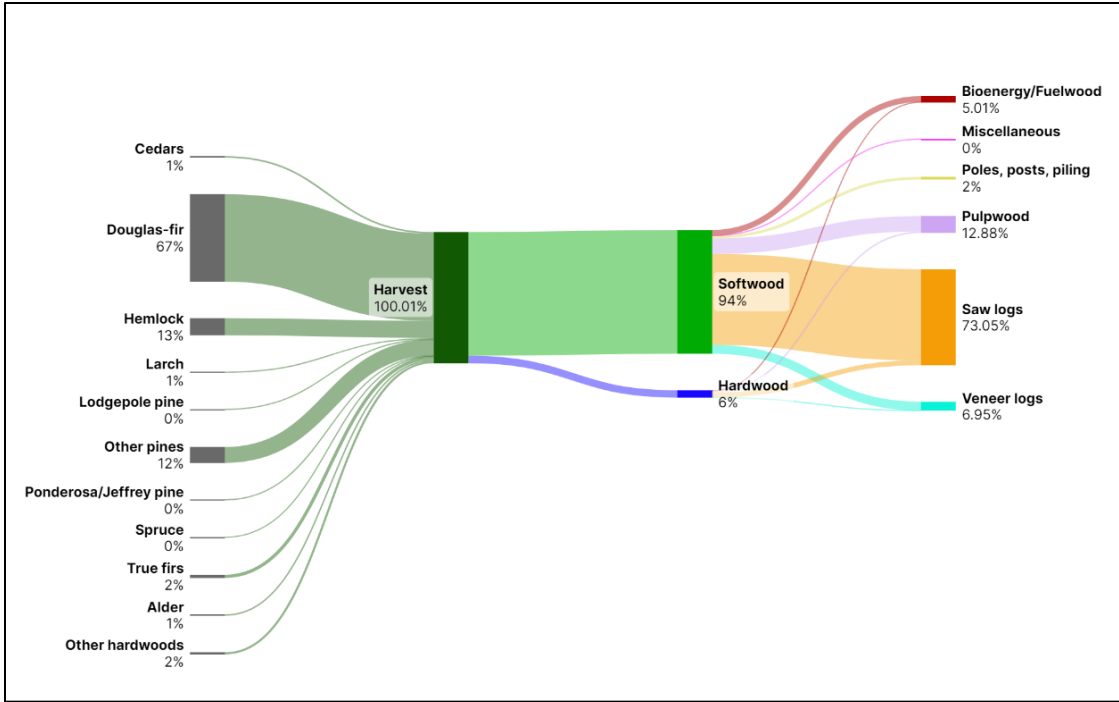
Figure 16 Allocation of wood products by forest species representing total harvest for Washington State (TPO 2018)
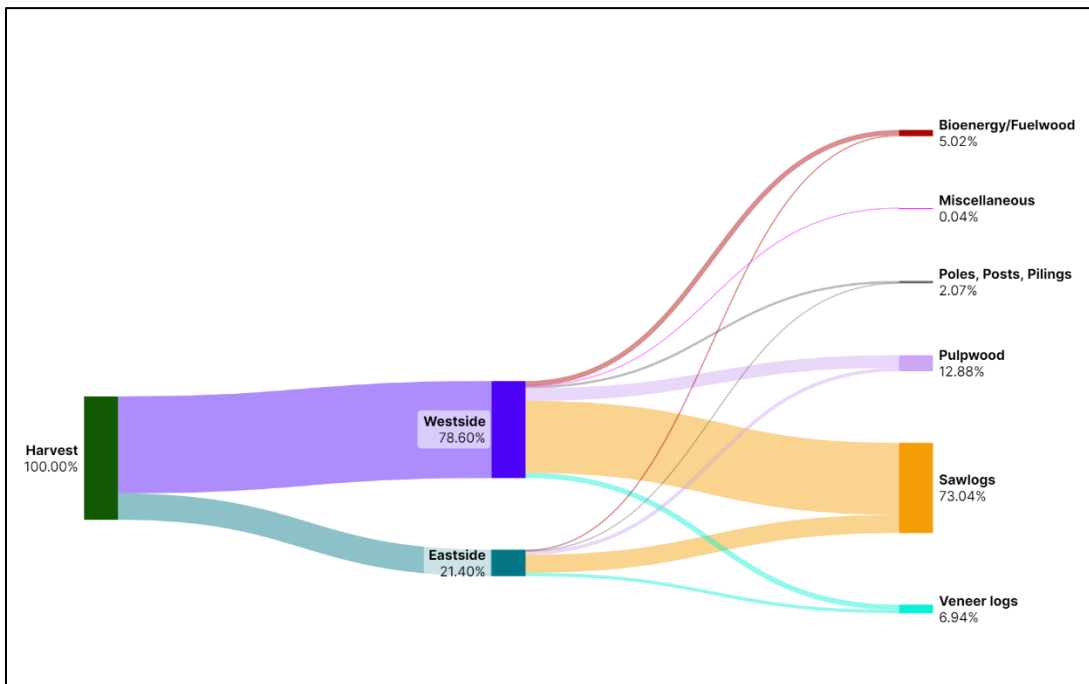
Figure 17 Allocation of wood products by west and eastside for Washington State (TPO 2018)
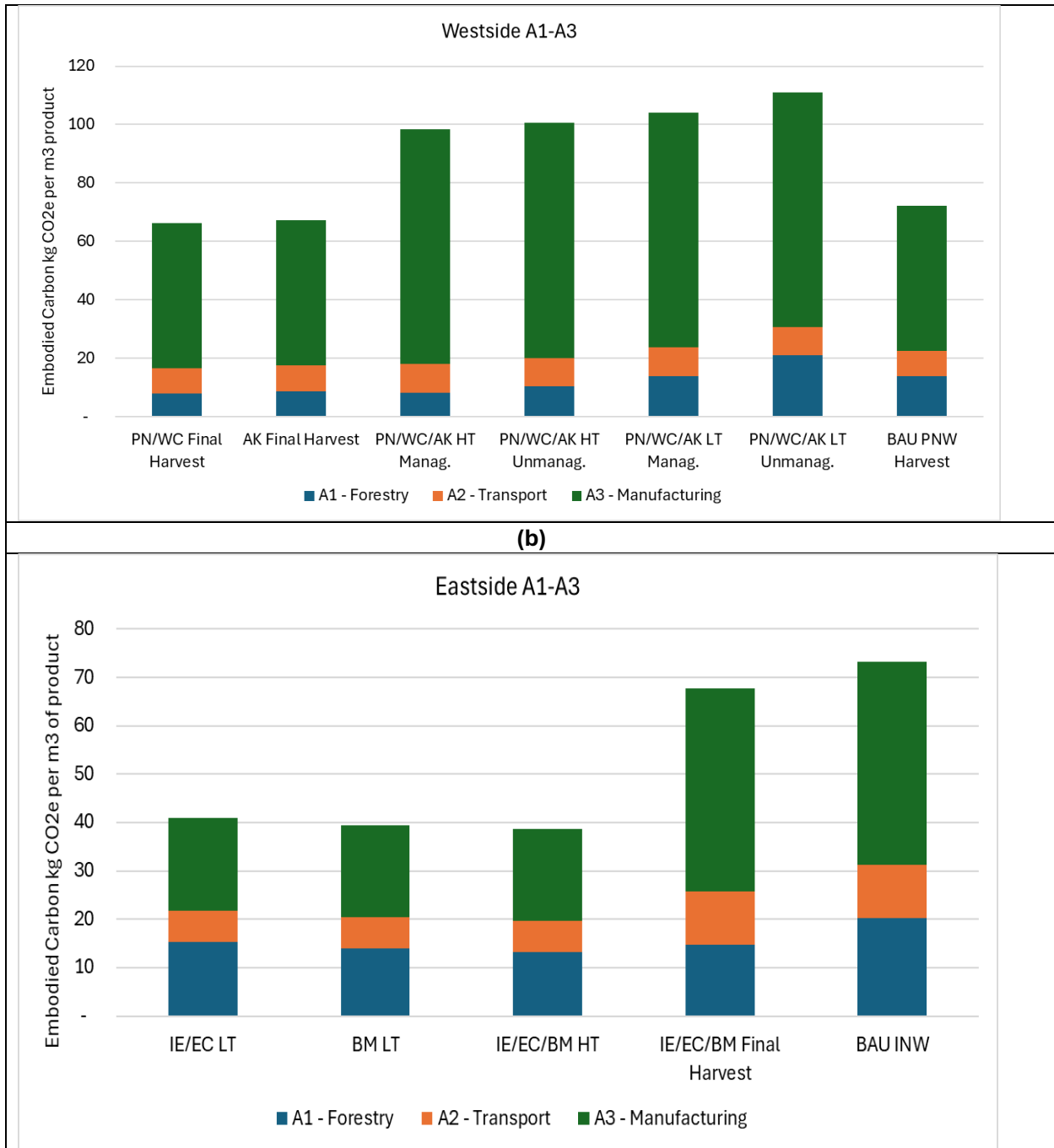
Figure 18 A1-A3 embodied carbon by life cycle stage for management scenarios using representative softwood lumber mills from western (a) and eastern (b) Washington. Assumes all harvest is sawlog
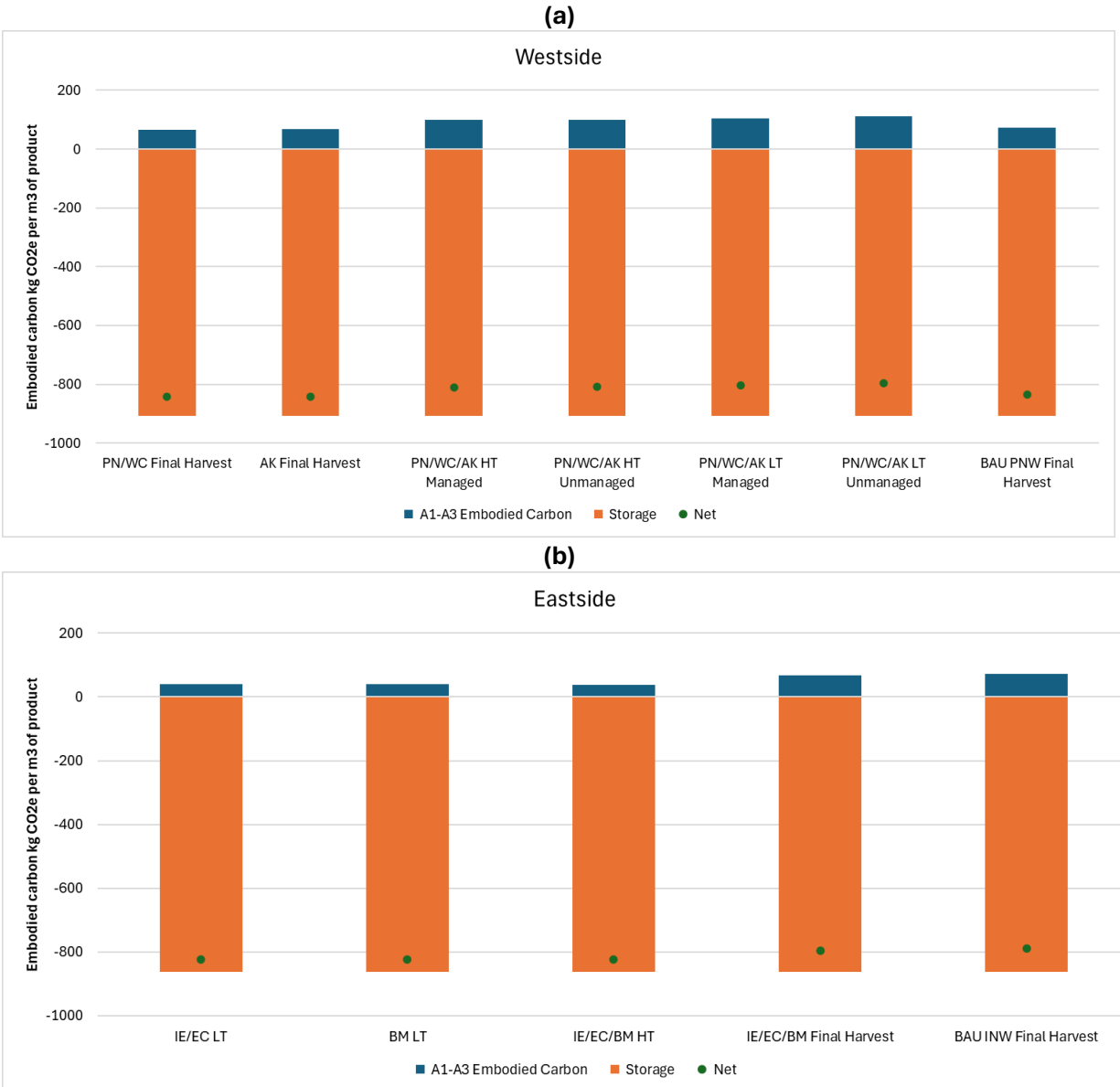
Figure 19 Embodied carbon, carbon storage, and net carbon for softwood lumber produced from each for management scenario for westside (a) and eastside (b) Washington

Figure 19 shows that for every cubic meter (m3) of sawn wood produced in Washington's sawmills, from 790 to 842 kg of CO_2e is stored in the product itself after accounting for the emissions it took to grow, harvest, haul and manufacture it. Example substitution assessments were developed to compare the use of SFLO wood products versus functional equivalents which show an additional 35 kg CO_2e of emissions are avoided by using wood in construction applications per square meter of wall area, or 1,666 kg CO_2e per m3 of sawn wood for a total carbon mitigation benefit of about 2500 kg CO_2e per m3 of sawn timber. The higher the volume removed per acre, and the more of that wood that is turned into long-lived products, the higher the carbon benefit of the HWP on a per acre basis.

Implications of Management Intensity on Forest and HWP Carbon Outcomes

In addition to the statewide harvesting LCA data inputs for the database tool, we also conducted a case study that explores the LCA impacts of management. This excellent dataset provides a rare examination of the trade-offs between low, moderate, and high intensity management. It has contributed significantly to the recommendations on 'improved forest management' for carbon market and carbon incentive programs as well as pointing the way for what is needed to incorporate 'longer rotations' as a credible, defensible market strategy. Carbon foot-printing developed from a Tale of Three stands was used to explore the range of carbon consequences from improved forest management in our westside forests. This long-term retrospective management experiment was fully documented by WFFA members, Bryon and Donna Loucks, over a 35-year period. We gratefully acknowledge their willingness to share detailed data on planting, thinning, density management and harvest. These data were used to compile and generate the summary shown in Table 9.

The 3 stands started out identical: planted with 600 Douglas-fir per acre and thinned at age 11 to 300 trees per acre. Stand 1 was left for 30 years and then harvested at age 41. Stand 2 had a commercial thin and then a final harvest at 43 years and stand 3 had 2 commercial thins and then a final harvest at year 45. The difference in log size is substantial, though the yield doesn't vary by much. Note that pulp volume (*) was converted to BF at 8.75 tons/MBF by the landowner. This conversion is carried through to the analysis of tons, carbon, and carbon footprint.

Stand 1 had stopped growing and was experiencing significant mortality and loss of live crown. Silvicultural treatment alternatives for such a stand are limited as thinning is unlikely to create a release in a meaningful timeframe given the lack of live crown. In addition, the instability of the remaining trees substantially increases their risk of windthrow while those crowns develop. Thus, the window of opportunity for improved forest management on the stand was largely closed. Under these conditions a harvest and replant scenario is likely to create the largest carbon benefit.

Stand 2 appears to be a sweet spot, both in terms of harvest value and its carbon sequestration per year potential. It generates family income on a 40-45-year time frame (every 2nd generation) but can be modified for longer rotations if the value and carbon benefit support that alternative.

The landowners acknowledged that Stand 3 was still growing well when it was harvested at 45 years. The stand could have been held another 10-15 years without much expected loss, though there was concern that individual trees would become too large to attain the high values received from the final harvest at age 45 because oversize logs are worth less, and sometimes a lot less, than logs with large end diameters less than 28".

Applying these case study results to the carbon footprint and storage analysis above generates an estimate that every acre of well managed forest land that is harvested offsets the emissions from 65-98 car-years from the lumber product storage and substitution benefit alone. This is a conservative value as it does not include the additional carbon stored in engineered wood products that are a co-product of producing sawn timber such as MDF (see Appendix 2 for

comparative analysis). Harvest of lower quality sites or poorly stocked stands reduces the benefit proportionately.

Table 9: A Tale of Three Stands silviculture, harvesting, and yield comparisons

Treatment Regime	Stand 1 - Low intensity	Stand 2 -Moderate intensity	Stand 3 -High intensity
Age at harvest	41	43	45
	Per acre values		
Pre-commercial thin - age 11	300	300	300
Stocking at final harvest	230	153	100
# commercial entries	1	2	3
Commercial Thin #1	0	4,500*	4,500*
Commercial Thin #2	0		4,273*
Gross Board Feet (BF)	27,972	27,629	29,935
Net BF Final harvest	25,808	26,485	27,927
Total volume removed (merch + non-merch)	27,972	32,129	38,708
Green metric tons removed	168	253	219
Metric tons of carbon removed	51	77	67
Metric tons of carbon per year in product	1.25	1.79	1.48
Log allocation across all stand entries			
#2 sawlog (>12" scaling diameter) export log	0.0%	41.0%	78.3%
9-11.9" export log.	53.3%	31.0%	
#3 and #4 sawlog (5-6" scaling diameter)	33.6%	21.0%	10.7%
pulp	9.4%	7.0%	11.0%
hardwood	3.7%		

The landowner, who also had significant forestry expertise, expected that if they had been able to leave Stand 3 for another 10-15 years it would have continued to accumulate volume and thus carbon, perhaps reaching 50,000 BF/acre by age 60. We used those estimates to conduct a scenario analysis on the yield and carbon consequences of managing Stand 3 as it had been managed by extending the rotation to year 60. The comparisons are shown in Table 10, for all parameters but log allocation as we do not have enough detail to speculate on log sort distributions for such a stand. While the metric tons of carbon removed is 55% higher for the extrapolation of stand volume by extending the rotation 15 years, the carbon removed per year is

only 17% higher and still does not equal the carbon removed/year by Stand 2 at 43 years. This interplay between density, growth, stand dynamics, soil productivity, (and probably a good deal of luck) means that there can be no one size fits all criteria or recommendation for either 'improved forest management' or 'extended rotations' when it comes to the carbon consequences associated with carbon flux (the amount removed from the atmosphere).

Table 10: Experienced and Extrapolated (*) harvesting and yield comparisons for extended rotation stands under managed conditions.

Treatment Regime	Stand 3 -High intensity	Stand 3 – Extended Rotation Pathway*
Age at harvest	45	60
	Per acre values	
Pre-commercial thin - age 11	300	300
Stocking at final harvest	100	85
# commercial entries	3	3
Commercial Thin #1	4,500	4,500
Commercial Thin #2	4,273	4,273
Gross Board Feet (BF)	29,935	50,000
Net BF Final harvest	27,927	46,646
Total volume removed (merch + non-merch)	38,708	58,773
Green metric tons removed	219	341
Metric tons of carbon removed	67	104
Metric tons of carbon per year in product	1.48	1.73

This case study illustrates how each stand is unique and should be assessed from the perspective of the potential range of options available. Until now that level of granular assessment has not been possible without extensive and expensive field surveys and analysis, including sophisticated silvicultural modeling. Improving on NRSIG Forest Genie should help make transparent the landowner choices for reasonable silvicultural pathways and the range of carbon consequences that can be expected under these pathways. Ideally these details can be automated so that either forestry navigators or experienced landowners can use the tool for planning and proposal purposes. Ultimately, improvements in granularity and estimation procedures will be needed for the tool to be accepted as part of the carbon assessment process for verifying carbon standards organizations (e.g. ACR, Verra, CAR). Ultimately, this level of granularity will be demanded by the carbon market and wood user community. That market demand has been voice loudly in the architecture community for several years and identified as a key gap in the 2020 wood in the circular economy workshop sponsored by CORRIM. More importantly, the development of these sophisticated AI tools and models will curtail instances of 'greenwashing' as regular measurements will be able to confirm or refute assertions of forest and land carbon accumulation.

Contributions to Harvested Wood Products Carbon Storage

In summary, Washington's SFLO play a critical role in the forest sector, including providing about 12%[19] of the harvested biomass for Washington's wood manufacturing facilities. Most of the harvested biomass (about 75%) is directed to sawmills for conversion to long lived wood products[20]. Analysis shows that for every cubic meter (m3) of sawn wood produced in Washington's sawmills, from 790 to 842 kg of CO2e is stored in the product itself after accounting for the emissions it took to grow, harvest, haul and manufacture it. Substitution assessments show an additional 35 kg CO2e of emissions are avoided by using wood in construction applications per square meter of wall area, or 1,666 kg CO2e per m3 of sawn wood for a total carbon mitigation benefit of about 2500 kg CO2e per m3 of sawn timber. Using case study results this translates to offsetting emissions from 65-98 car-years for every acre of well managed forest land that is harvested. Harvest of lower quality sites or poorly stocked stands reduces the benefit proportionately. These estimates do not include the additional carbon stored in engineered wood products that are a co-product of producing sawn timber.

Forest Landowner Carbon Flows (Flux)

In the analysis above we focus on carbon stocks both on and off the forest and the attendant emissions associated with harvest to derive carbon storage values. Comparison of these storage values leads to arguments about forest rotation length and management intensity, but as shown, the highest carbon storage in the forest and in the HWP doesn't necessarily translate into the highest flux – the carbon accumulation per unit of time.

It is this flux that is measured and remeasured over the term of a carbon project to ensure that the forest is continuing to remove the carbon from the atmosphere. A more detailed account of carbon flux that includes the forest (average carbon sequestration over the entire forest estate), and emissions from mortality, decay, harvest, manufacturing, including residual forest and product storage was conducted by Ganguly et al, 2022. They used Forest Inventory and Analysis (FIA) data from Oswalt et al 2019 combined with Washington timber harvest data and mill allocations, including LCA data such as that shown for softwood lumber (Figure 18) to derive the carbon flux by landowner type shown in Table 11. As FIA data aggregate SFLO and tribal data, these owner types were combined for this analysis. These data show that there are ample opportunities for improved forest management to both increase standing carbon inventory (Tables 1-3)) and increase carbon sequestration (flux) (Table 11), on SFLO lands in Washington state.

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[19] Palmer, Marin; Kuegler, Olaf; Christensen, Glenn, tech. eds. 2018. Washington's forest resources, 2007–2016: Ten Year Forest Inventory and Analysis report. Gen. Tech. Rep. PNW-GTR-976. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 75 p.

[20] TPO 2018

Table 11. Forest and wood product carbon flux by owner type for Washington State.

| WA Owner Group | Forest Account | | | | | Wood Product Account | | | Additions to Capital Accounts | Retained Carbon Ratio |
	Current account (sequestration/acre)	Mortality/Decay (includes landfill)	Sequestration less decay	Net sequestration: sequestration	Forest Storage	Wood Products	Emitted (burned or otherwise depleted in mill) (by subtraction)	products less C used	Forest + product storage	Stock to Flux Ratio
Industry	4.93	1.65	3.28	67%	0.34	2.44	0.50	1.94	2.27	46%
DNR	4.09	1.79	2.30	56%	0.24	1.59	0.47	1.12	1.36	33%
USFS	2.88	2.05	0.83	29%	0.72	0.09	0.02	0.08	0.80	28%
SFLO/ Tribal	2.79	1.16	1.63	58%	0.93	0.58	0.11	0.47	1.40	50%

The detailed analysis possible from the Forest Genie estimation shows that there are specific interventions that are likely to yield substantial carbon improvements on SFLO lands. It also can show exactly where they are located. The Forest Genie dataset was used to classify the parcels and forest acres meeting criteria related to specific management concerns for SFLO including aging hardwoods, overstocked forests, and understocked forests. Tables 12-14 summarize these data and Figures 20-22 show the approximate location of these parcels.

Table 12. Summary of SFLO hardwood dominated (hardwood proportion >= .5) forests by QMD size class using prediction rasters and the Forestland Database.

Half State	QMD Size Class	Number Of Parcels	Forest Acres
West	4 to 8 in	61,577	89,307
	8 to 12 in	117,183	215,518
	12 to 16 in	130,280	242,769
	> 16 in	88,343	76,041
East	4 to 8 in	13,998	36,401
	8 to 12 in	18,647	86,315
	12 to 16 in	13,613	26,889
	> 16 in	6,841	5,627

Table 13. Summary of SFLO dense (RSDI > .55) forests by QMD size class using prediction rasters and the Forestland Database.

Half State	QMD Size Class	Number Of Parcels	Forest Acres
West	4 to 8 in	1,713	596
	8 to 12 in	50,135	53,194
	12 to 16 in	123,657	184,849
	> 16 in	123,240	191,552
East	4 to 8 in	595	180
	8 to 12 in	24,304	23,855
	12 to 16 in	47,451	83,083
	> 16 in	36,128	46,925

Table 14. Summary of SFLO sparse (RSDI < .4) forests by QMD size class using prediction rasters and the Forestland Database.

Half State	QMD Size Class	Number Of Parcels	Forest Acres
West	4 to 8 in	143,970	380,739
	8 to 12 in	169,335	316,901
	12 to 16 in	164,335	132,864
	> 16 in	100,632	31,344
East	4 to 8 in	66,467	290,622
	8 to 12 in	75,733	881,364
	12 to 16 in	74,776	438,355
	> 16 in	42,096	34,187

Figure 20. Map of SFLO parcels with hardwood dominated (hardwood proportion >= .5) forests by QMD size class.

Figure 21. Map of SFLO parcels with dense (RSDI > .55) forests by QMD size class.

Small Forest Landowner Parcels with RSDI < .4 by QMD Size Class (minimum 20 acres)
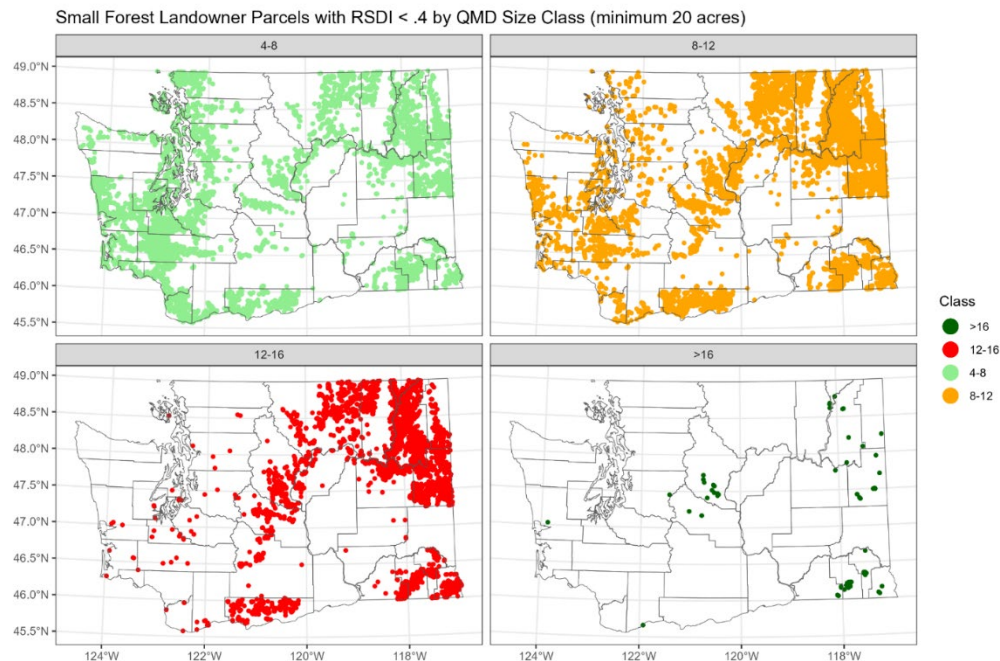
Figure 22. Map of SFLO parcels with sparse (RSDI < .4) forests by QMD size class.

The Forest Genie tool provides a significant advancement in our understanding of the extent and spatial distribution of improved forest management opportunities. This means it removes the need to create general categories of 'good practice or improved forest management' because it permits site specific silvicultural recommendations to be developed based on current inventory and its expected trajectory through time based on known forest stand dynamic principles.

If regularly updated and augmented as proposed in our recommendations, we believe the Forest Genie will become the 'state of the art' for forest land carbon assessment. It will streamline comparisons between areas for protocols that use dynamic baseline assessments such as the FFCP; and with refinements we think it could be used to provide confirmation of carbon increases or decreases for lands enrolled in a carbon program including for regulatory programs like the Washington Forest Offset Protocol.

Eastside Forests – Our Unique Challenge

The Department of Natural Resources (DNR) 20 year forest health strategic plan identifies a significant portion of eastern Washington's forests at elevated risk for wildfire. SFLO own approximately 18% of forest land in eastern Washington. DNR fire risk assessments indicate that about 17% of the acres needing treatment to reduce fire risk are on SFLO lands (Figure 23). Management activities that support forest health are needed in our dry, fire-prone eastside forests where often carbon sequestration has nearly stopped due to over-crowding, and the risk of senescence and catastrophic loss is high. Given the ecology and condition of these forest types, common carbon market solutions such as longer rotations, no-touch management, and the maintenance of high carbon density forests are inappropriate.

However, solutions that generate durable carbon stores and support forest resilience hold great promise. Biochar produced from low value wood and forest residues can meet both objectives. In our dry eastside forests producing biochar from forest thinning and residue recovery is a particularly effective method of reducing wildfire risk while creating durable recalcitrant carbon for use in forests, farms, and industrial applications. In both our eastside forests and wetter westside forests, biochar additions can enhance soil structure, leading to improved growth while utilizing low value waste streams that would otherwise release carbon to the atmosphere through burning or decay. In both cases, biochar creation provides for net positive outcomes over time, but markets for the biochar produced and/or the carbon value, have not been actively developed.

There are potential carbon market opportunities for fire risk reduction activities if the state establishes incentives and policies that work in concert instead of against one another. Our chief challenge involves reducing the significant regulatory barriers preventing the implementation of biochar-based technologies, including the use of air-curtain burners that have been used extensively in other jurisdictions as a low cost, clean alternative to open burning. Beyond solving these regulatory burdens, it will also be necessary to enhance infrastructure and create coordinated approaches to advance markets for biochar.

Figure 23: Areas of high risk for wildfire in eastern WA (a) and eastern Washington Forest Land Ownership Patterns (b). Source: DNR 20-year forest health plan
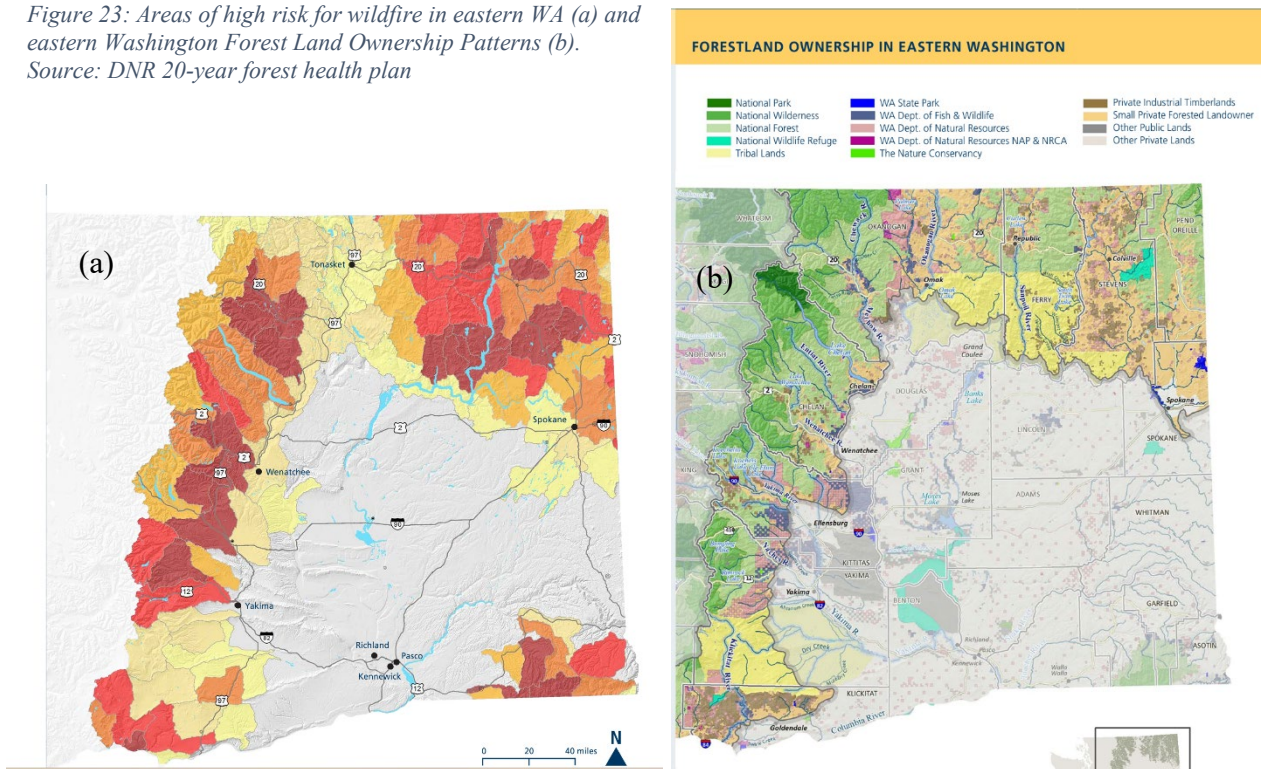
If We Build it, They Will Come – Or Will They?

History is littered with programs, promises, and "great" ideas that went nowhere. And they went nowhere because the people they were aimed at weren't interested in buying into them. The benefit of having a workgroup comprised primarily of small forest landowners – albeit engaged small forest landowners – means that a lot of "great" ideas immediately ended up on the cutting room floor. It's why our recommendations on Washington's Forest Offset Protocol are so succinct. And why our endorsement of supporting the NRSIG effort to improve data is so whole-hearted. But an examination of SFLO priorities, concerns, needs, and fears is a lot more difficult to categorize and 'solve for' as we discuss in this section of the report.

Engaged Small Forest Landowners

Of the 218,000 SFLO in Washington state, there is a small cohort, (of unknown number but probably about 8-10,000 or so based on mailing list numbers), that forestry professionals at the Department of Natural Resources (DNR), Washington State University (WSU) Forestry Extension, Natural Resource Conservation Service (NRCS), the Conservation Districts, and the landowner organizations ((WFFA, Washington Tree Farm Program (WTFP) and Northwest Natural Resource Group (NNRG)) would consider as 'engaged'. These are the people that show up at educational events sponsored by the above agencies and groups, join landowner groups, request assistance from any of the above agencies, and generally are actively pursuing solutions to the conditions they see on their forestland. They are the early adopters, the active managers, and the activists that show up to testify when they hear of legislation that might affect them. We conducted outreach to this group to ascertain their interest in participating in carbon incentive programs. Consistent with the outcomes listed in the UW 2021 landowner report, they were very interested in participating in carbon programs, or at the very least learning more about them, even if it wasn't entirely clear what they would gain from the effort. The survey was introduced with the following explanation:

> *"This survey is intended to gauge forest landowners' interest in programs and practices to increase carbon sequestration on their land. The information gathered by this survey will be used to recommend policies and programs to the Washington State Legislature, and to expand the ecosystem services marketplace for forest landowners. With a more detailed understanding of landowners' capabilities and interests in adding carbon sequestration to their suite of management activities, we can propose more effective and accessible programs for landowners. The ranges of potential financial compensation for carbon sequestration practices listed below represent what might be expected with existing and future carbon offset and other incentive programs. This survey does not include personally identifiable data, and it will be used in aggregate to understand the dynamics and desires of the diverse forest landowner community."*

The survey had three components: Basic demographic information including forest parcel size and location (Westside/Eastside); Landowner management priorities (similar in both the categories and responses to the National Woodland Owners Survey); and Willingness to

implement practices for increasing carbon sequestration and acceptable levels of financial compensation for four different practices that could potentially have a carbon benefit. The responses on management priorities confirmed the diverse interests of SFLOs as found in many previous surveys. Any new focus on carbon sequestration will be balanced with other ecological and financial objectives.

The survey did not address barriers or concerns, which will be discussed next under the Ethnographic Futures Research findings. The survey was designed as a "What If?" exercise: "Would you be willing to do this practice if you were financially compensated?"

Two landowner groups were surveyed including members at the WFFA Annual meeting in May 2023 most of whom are actively managing of which 65% were certified under either the ATFS or FSC forest certifications (or both). Additional surveys were completed at WSU field days in eastern and western Washington. These engaged landowners attending these all-day educational events also had a significant portion of certified forests among them: 33% were certified to the ATFS standard and some were also certified to the FSC standard.

Notes of Import:

- Missing from Survey: Non-managing landowners (which would have difficulty answering questions about forest management practices and associated financial considerations).
- Similar results were found across all groupings with some notable/predictable differences.

Key takeaways:

1) There is strong SFLO interest in all proposed carbon pathways (67-88% participation willingness)
2) SFLOs don't always require full compensation for implementing new practices (accepting a minimum 52-66% cost share)

The survey asked questions regarding willingness to implement and minimum acceptable compensation for the four potential carbon smart forestry practices as shown in *Table 15* and *Table 16* respectively. The practices included afforestation – i.e. planting trees on areas that are non-forest now – as distinct from reforestation which is required by law after harvest unless you are converting to non-forest uses. They also include 'improved forest management', which is a catchall term that may include increasing stocking, decreasing stocking, addressing forest health concerns, mortality, or species issues depending on the condition of the forest relative to its capability. Extended rotation refers to increasing the age at which the land is harvested under the assumption that it is currently harvested before it reaches maximum carbon storage. Legacy forest management describes management action to put forests on a trajectory towards 'desired future condition' in areas that are currently off limits to harvest, usually due to regulation.

Table 15: Survey of Engaged Landowners – views on willingness to participate in various carbon strategies

Participation Willingness - Percentage of Respondents Answering "Yes"		
Intervention Type	Westside	Eastside
Afforestation	70%	67%
Improved Forest Management	88%	89%

Extended Rotations	71%	73%
Legacy Forest Management	84%	83%

Table 16: Survey of Engaged Landowners – Minimum acceptable compensation to participate in carbon incentive programs.

Participation Cost - Weighted Mean of Minimum Acceptable Compensation for Intervention			
Intervention Type	**Westside**	**Eastside**	
Afforestation	55	66	**Percent of cost of implementation**
Improved Forest Management	52	57	**Percent of cost of implementation**
Extended Rotations	6	5	**Percent of timber value paid annually for deferred harvest**
Legacy Forest Management	55	62	*** Percent of total timber value for one-time compensation**

Results show a preponderance of 'engaged' SFLO are willing to conduct carbon smart forestry practices, even if they aren't that clear what they are and don't have any information regarding what that would entail. Consistent with other research and observations of SFLO behavior, they don't necessarily have to be fully compensated for all costs associated with these improvements, though there is significant variability in that finding. These are the early adopters that we would test all our recommendations with and adjust as necessary. They are also the core of a community of practice that can serve as beacons to their far-flung neighbors and associates.

Reaching Those that Don't Currently Participate

If optimistically 8-10,000 SFLO are engaged landowners, that means over 200,000 SFLO are not currently reached by agency or non-profit outreach. That is a lot of land, social capital, and opportunity to leave on the table as we develop programs to address climate mitigation and support a burgeoning SFLO community. The question remains, how do we reach them? What are the incentives that work? And more importantly, what are the disincentives?

The Ethnographic Futures Research (EFR) methodology is designed to elicit patterns, themes, and insights from long form interviews which are used to develop research informed recommendations. EFR as a participatory research method is particularly well suited to documenting SFLO's perspectives, breadth of their experiences, futures desires, and geography. The qualitative data analysis process identifies recurring themes used to develop future scenarios.

We used this method to gather as broad of a representative sample as we could with our limited funding to provide the deep insights from SFLOs concerning the incentives and disincentives that would positively and negatively impact their future participation in carbon offset and/or incentives programs. This was easier said than done. The broad cultural and geographic range of SFLOs, the enormous population (218,000), their remote location and lack of reliable internet

access, contrasting and potentially strongly held opinions, attitudes, bias, values, beliefs, and behaviors of the population, and the challenges inherent in locating and contacting non-traditional SFLO without a comprehensive census mean that the EFR effort, while valuable, should be considered a reasonable starting point to develop program outreach for small forest landowners. It has yielded solid preliminary insights which suggest new avenues of inquiry may be required to more robustly design, test and validate policies and programs as this work develops. In particular, our programmatic recommendations regarding outreach to non-traditional and underserved communities speak to this need.

The small-scale Ethnographic Futures Research study identified common perceptions and barriers to participating in a carbon market or carbon incentive program. It yielded results that were not what we expected. We highlight the many costs and barriers to participation below, but the ultimate conclusion bears the most exposure and consideration. The EFR report concludes with a nuanced understanding of the driving factors influencing SFLOs' decisions regarding forest management and carbon sequestration. What we also heard loud and clear is that there is an important task we need to accomplish to overcome social barriers, particularly for recruiting and onboarding new SFLOs entering and participating in a carbon program. That task is to 'grow the community' of SFLOs to increase willing engagement, try new things, and feel like they have a safety net (financially, technically, socially) that will support them as (we all) advance into an uncertain future.   Full results of the Technical Report are presented in Appendix 5.

The Ethnographic Futures Report highlights a critical need for policy adjustments, educational support, and technical assistance to overcome the barriers to participation thereby decreasing the disincentives to engagement. The study's recommendations focus on creating an enabling environment for SFLOs, ensuring their practices are both sustainable and economically viable. By addressing these recommendations, there is a potential to significantly increase SFLOs' engagement in carbon sequestration efforts, thus contributing to Washington State's broader environmental and climate mitigation goals. This study suggests that a balanced approach to policy, programmatic and practice-oriented recommendations will reduce barriers SFLO perceive as disincentives to participation. At the same time, it will increase incentives for adoption of a new carbon credit market that supports climate smart forestry practices. Of major importance is to emphasize the common ground held in high value by the SFLOs who participated in this study and confirmed by other relatively recent research: namely, a desirable future is one where people can enjoy the beauty, scenery, tranquility and privacy of their forests; a place where the wildlife thrive on the environmental benefits that come from healthy water and resilient forestlands. This finding is consistent with the findings from our survey of the 'engaged' SFLO. In short, any new focus on carbon sequestration will be balanced with other ecological and financial objectives.

EFR Findings: Barriers to Entry and Engagement in Carbon Market and Incentive Programs

1) Regulatory and Bureaucratic Challenges
   a) Permitting Process: The technical complexity and time-consuming nature of the permitting processes are significant barriers, especially for SFLOs lacking professional experience, training, or resources to navigate these requirements effectively.

b) Changing Regulations: Difficulties in navigating frequently changing regulations and bureaucratic apparatus emerge as critical themes. Even experienced SFLOs find the regulatory and compliance landscape daunting, exacerbating challenges to accessing programs beneficial for sustainable forest management.

2) Operational Challenges
   a) Physical and Labor Limitations: Aging SFLOs face declining physical capabilities and large physical challenges in managing forests, particularly during the initial phase of Climate Smart Forestry Practices, which require substantial hard labor.

   b) Management and Labor Constraints: Limited resources for forest management practices, costly and hard-to-find labor, and the aging demographic of landowners operating on fixed incomes significantly impact SFLOs' ability to manage their forests effectively.

   c) Scale and Property Size Limitations: Smaller properties face challenges in achieving economies of scale, which larger properties benefit from, making it difficult for SFLOs to qualify for various programs and incentives.

3) Financial Constraints
   a) High Upfront Costs: The perception of high upfront costs for implementing sustainable forest management practices is a major barrier. This includes costs for deferred forest maintenance and the initial investments needed for engaging in the Carbon Credit Market
   .

   b) Small Return on Investment (ROI): The combination of rising costs of labor, equipment, and transportation, along with the increasing distance to mills, reduces the potential ROI for SFLOs. This financial disincentive impacts the willingness of SFLOs to participate in Climate Smart Forestry Practices.

4) Market-Related Issues
   a) Market Access and Viability: SFLOs face significant challenges integrating into existing carbon markets due to the unpredictability and fluctuation of carbon credit prices. This market volatility complicates financial planning and investment in sustainable practices.

   b) Development Pressures: Increasing development pressure leads to forest fragmentation, making sustainable management and profitability more difficult for SFLOs. This trend is driven by the subdivision of forest lands and the rise in the number of smaller land parcels.

5) Technical Knowledge and Resource Gaps
   a) Lack of Expertise: Many SFLOs report limited technical knowledge necessary for effective forest management and carbon sequestration, further exacerbated by the high costs of accessing specialized knowledge and resources.

   b) Information and Support Access: Difficulties in accessing consistent, up-to-date research, best practices, and technological advancements hinder SFLOs from implementing

sustainable practices. The variability in information from different agencies adds to the confusion and inefficiencies.

6) Environmental and Ecological Concerns
   a) Climate Change Impacts: Changing weather patterns, increasing prevalence of wildfires, pests, diseases, and the spread of invasive species significantly impact forest health, posing substantial challenges to SFLOs.

   b) Natural Disasters: The increasing frequency and scale of natural disasters, such as wildfires, pests, and diseases, heighten the vulnerability of SFLOs, necessitating enhanced risk management and disaster preparedness strategies.

   c) Biodiversity and Ecosystem Balance: Balancing carbon sequestration practices with the preservation of biodiversity and ecosystem health is a complex challenge for SFLOs. Effective carbon sequestration practices must not compromise the ecological integrity of forest ecosystems.

While many of these barriers have been identified in the regulatory and market analysis section of this report based on technical observations from project developers, the nuance and depth provided by the EFR study adds power to the recommendation that it is necessary to build, or build upon, extant Communities of Practice to overcome these barriers. Making the current tent of SFLO community-based organizations, such as that provided by WFFA, ATFS, or NNRG membership, broader, wider, and more welcoming is a first step. Coalescing around the idea that we are all in this together, and can all learn something from one another, is a powerful message to bring forth.

EFR Findings: Pathways for Small Forest Landowners (SFLOs) Engagement

1) Policy Pathways

   a) Regulatory Simplification
      i) Streamline Permitting Processes: Develop clear, concise, and streamlined permitting processes to reduce complexity and processing times. Implement digital platforms to facilitate application and tracking, ensuring consistency across agencies.

      ii) Stabilize Policy Frameworks: Create stable, predictable, and long-term policy guidelines that align federal, state, and local regulations. This stability will help present and future SFLOs plan and invest in sustainable practices with confidence.

2) Financial Incentives
      i) Tax Incentives: Introduce tax incentives for SFLOs participating in Climate Smart Forestry Practices and the Carbon Sequestration credit market. This could include property tax reductions (Add a new Climate Smart Forest Designation" that does not explicitly require harvesting of the forest for many SFLOs who are not and do not intend to be farmers) or credits for certified sustainable practices.

ii) Carbon Credit Subsidies: Provide subsidies or financial incentives large enough to offset the initial costs of entering the carbon credit market, particularly for smaller landowners.

3) Market Support
   i) Stable Carbon Market Pricing: Develop policies that stabilize carbon credit prices to reduce market volatility and provide predictable revenue streams necessary for SFLOs.

   ii) Market Access Facilitation: Create cooperative models to aggregate land and improve market leverage, making it easier for SFLOs to access and benefit from carbon markets as well as easier for the regulatory oversight needed to sustain the program in perpetuity.

4) Program Pathways
   a) Technical Assistance and Education
      i) Technical Support Programs: Establish comprehensive technical support programs offering consulting services, expert-led workshops, and on-site evaluations to guide SFLOs in sustainable forest management.

      ii) Educational Initiatives: Increase the availability of educational resources such as online courses, field days, and regional conferences focused on Climate Smart Forestry and carbon sequestration techniques.

5) Resource and Financial Support
   i) Grants and Subsidies: Provide grants and subsidies for SFLOs to cover the costs of implementing sustainable practices, purchasing equipment, and accessing necessary resources.

   ii) Flexible Financing Mechanisms: Develop financing options tailored to SFLOs' needs, including low-interest loans and deferred payment plans to support initial investments in forest management.

6) Community and Cooperative Models
   i) Community-Based Resource Sharing: Encourage the development of regional or local resource-sharing platforms, such as tool libraries and cooperative purchasing agreements.

   ii) Cooperative Management Groups: Promote the formation of cooperative management groups to pool resources, share labor, and achieve economies of scale, improving operational efficiency and market access.

7) Practice Pathways
   a) Sustainable Forest Management
      i) Adaptive Management Plans: Develop adaptive management plans tailored to the unique conditions of each forest, incorporating best practices for biodiversity, ecosystem health, and carbon sequestration.

ii) Regular Training and Updates: Implement regular training programs for SFLOs on the latest sustainable management techniques, ensuring they stay updated with current research and practices.

iii) Succession Planning: Create a new Climate Smart Land Trust that would create a SFLOs pathway to continued management when the present and aging owner is no longer physical and financially able to manage the forest sustainably.

b) Risk Management and Disaster Preparedness
i) Disaster Risk Reduction Programs: Introduce programs focused on wildfire prevention, pest and disease management, and other risk reduction strategies to enhance forest resilience.

ii) Emergency Response Resources: Provide resources and support for emergency preparedness and response, helping SFLOs mitigate the impacts of natural disasters.

c) Technological and Operational Support
i) Innovation in Tools and Technology: Invest in the development and dissemination of advanced tools and technologies that reduce labor intensity and improve the efficiency of forest management practices.

ii) Mentorship and Peer Support Networks: Establish mentorship programs that connect novice SFLOs with experienced SFLO practitioners, facilitating knowledge transfer and community support.

Many of these policy, program, and practice pathways exist today. But from the research it appears that they are either not well known, hard to access and/or underutilized according to our interviewees. But the detail is clear: if SFLOs can be effectively supported in their efforts to engage in carbon market and incentive programs, then these barriers and challenges must be addressed. Think of it this way, creating well aligned and effective incentives is only half of the job: the barriers, challenges, and limitations are disincentives that must also be reduced or eliminated for SFLOs to be able to effectively sustain their movement along the pathway from unengaged to actively involved in the future of their forests.

EFR Findings: Future Scenarios

As part of the EFR process, SFLO were asked their views about how these see the future 20 years forward under two scenarios: one where we are able to mitigate climate change and one where we do not. The scenarios are in stark contrast: nearly apocalyptic to pollyannish which is somewhat common for Americans who struggle to imagine a realistic and possible desirable future and a probably undesirable future.[21] They speak to the needs and fears of those who do

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[21] According to my work and discussions with the late Stanford Professor Emeritus, who popularized this research methodology around the world, lead to his discovery that Americans have a recognized tendency to have a strong bias of viewing historical events and cultural practices through the lens of contemporary norms and values which can distort our interpretation of the past and influence future decision-making. That means we have a natural

own forest land and what they need to ensure the future is on the desirable path. Here the return on investment is measured in social cohesion, forest health and resilience and calm, in addition to potential of carbon benefits and finances.

Future Scenarios for Small Forest Landowners

- Undesirable Future (2044):

    - Climate Impacts: Severe droughts, reduced snowpacks, and increased wildfires due to climate change.

    - Forest Health: Overstocking, short-sighted exploitation, invasive species, and disease lead to forest degradation.

    - Urban Pressure: Development pressures fragment forests, reducing ecological value and biodiversity.

    - Demographic Shifts: Aging landowners without heirs result in land neglect or sale, increasing vulnerability to environmental threats.

- Desirable Future (2044):

    - Sustainable Management: Increased engagement in carbon sequestration and Climate Smart Forestry Practices.

    - Community and Innovation: New generation of landowners driven by state incentives and sustainable product innovation.

    - Balanced Policies: Supportive government framework encouraging sustainable management without excessive restrictions.

In order to move towards a more desirable future there are some financial, regulatory, technical, and biological challenges to address. None are insurmountable, but they emphasize the need for comprehensive, supportive, and adaptive approaches to overcome barriers and enhance participation.

Patterns and Themes Identified

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tendency to have a limited imagination about the future, he calls it Tempocentrism. The value of this concept for us is to challenge ourselves to look beyond our limitations, looking forward using our best understanding of trends, trajectories and experiences to prevent the negative undesirable future from becoming and encourage a commonly held positive desirable into existence. To do otherwise and make no changes to our behavior the driving force of climate change, scientifically speaking, will likely play out as the Intergovernmental Panel for Climate Change annual reports describe. The good news for us is it turns out Small Forest Landowners learn from their experience managing their forests and realize the practical ecological timeline of the forest moves well beyond our temporal limitations on this earth. The older the SFLO is the more able they are to imagine a future of the forests.

- Financial Challenges:

  - High Costs: Upfront costs for implementing sustainable practices are perceived as significant barriers.

  - Small ROI: Rising costs of labor, equipment, and transportation reduce potential returns on investment for SFLOs.

  - Market Access: Distance to mills and market volatility further complicate financial viability.

- Regulatory and Bureaucratic Challenges:

  - Complex Permitting: Technical complexity and time-consuming permitting processes deter participation.

  - Changing Regulations: Navigating frequently changing regulations and bureaucratic requirements is difficult for SFLOs.

- Technical Knowledge and Resource Gaps:

  - Expertise and Resources: Limited technical knowledge and high costs of accessing specialized resources hinder effective forest management.

  - Information Access: Inconsistent information from various agencies creates confusion, highlighting the need for better support and education programs.

- Environmental and Ecological Concerns:

  - Climate Change: Increasing wildfires, pests, and diseases pose significant threats to forest health.

  - Biodiversity: Balancing carbon sequestration with the preservation of biodiversity and ecosystem health is complex but essential.

Environmental Justice and Underserved Communities

In addition to the EFR work, a subcommittee gathered what data exists on environmental justice considerations for the CWG. There is nearly a complete lack of information on underserved communities as identified in the Climate Commitment Act. Based on 25 years of observation at WSU forestry field days, the majority of Washington's engaged SFLO are Caucasian and by virtue of their land ownership, wealthy (at least relative to their neighbors). In many cases, women and men share ownership and decision-making. Anecdotally there are some women-owned and managed forests as well, though no specific data are available on their numbers either.

Given there is so little data to make informed decisions on, we can only identify the obvious potential barriers for participation by SFLO from historically excluded and systemically

oppressed communities. The primary barrier to participation in carbon markets by these communities is, first and foremost, a lack of access to forestland. Our focus must necessarily be on creating pathways to ownership. Barriers to ownership include, but are not limited to:

1) The high cost of forestland which, in areas with severe development pressure, is prohibitive;

2) Lack of awareness of resources and expertise, which are essential to support active management and stewardship of forestland. Applying climate smart forestry practices arguably necessitates an even greater level of forestry acumen. Research indicates that minority SFLO are less aware of existing networks of expertise than their Caucasian peers, and less trustful of these resources.

3) Lack of equity / representation in communities of support. SFLO typically have many communities of support available to them, ranging from local and regionally based Federal agencies like the Natural Resources Conservation Service and the Soil and Water Conservation Districts to state foresters and watershed councils, as well as nonprofit organizations like the Washington Farm Forestry Association. However, underserved populations may not see themselves represented in these communities—if they are even aware of them—and there may be few, if any, neighbors like themselves to call upon for advice and assistance.

4) Discriminatory practices, which have limited access to property, equity, and wealth generation. The well-documented history of redlining that has prevented people of color from accessing loans or purchasing properties in urban communities may be considered a proxy for challenges faced in rural communities.

Succession Planning and ForestMatch.org

As part of its due diligence, the Carbon Workgroup reviewed the websites of every state-level small forest landowner organization in the US to assess the implementation of efforts related to climate smart forestry.

The Maine Woodlands Owners (MWO) is of particular interest on two fronts. MWO may be the first and only SFLO nonprofit in the country responding to the urgent demographic reality of aging forest landowners—often without heirs—who wish to see their legacies sustained rather than lost to development. In 1990, MWO created a forest land trust to accept properties and easements. Across the state, the trust now manages over 11,000 acres of conserved working forestlands, which continue to provide carbon storage, timber production, and access for recreation, including hiking and hunting. Receipts from active forest management cover MWO's costs as well as county taxes on the properties.

We recommend developing a similar approach in Washington State. Working forestlands are quite different from the property types which local land trusts typically manage. As a result, SFLO are unlikely to meet their specialized needs absent a tailored option. The Family Forest Foundation, a 501 c(3) has stepped forward to be an example vehicle for this recommendation.

To foster transition to a new generation of small forest landowners, we envision establishing a 'forest matching' service that links older small forest landowners with no heirs, to youth with a yearning to establish that connection to the land. In the WFFA community we have seen examples of this on an individual basis, but nothing is formalized, and the success rate in transferring to the next generation is unknown. Our ForestMatch.org idea would be implemented as part of the development of our Community of Practice organizational structure.

Finance Models, Incentives, Payments, and ROI

Potential ROI

Providing tools to small forest landowners to help them address fire risk, improve forest stand condition and sequestration potential, stem the tide of conversion, and make positive contributions to the wood products storage are all part of a large matrix of opportunities that will produce substantial contributions towards meeting Washington's climate goals. For example, if policies supporting keeping forests as forests were successful at reducing conversion, for every 1% reduction in forest land conversion the carbon benefit would equal at a minimum of 3.8+% or nearly a 4:1 return on investment. This value assumes that the converted acres represent the average values in Table 1 and 2, and accounts for carbon stored in harvested wood products with average substitution benefit. If those same acres were managed to capture excess mortality from insects and disease and implemented improved forest management activities, then the carbon benefit would increase by another 2.6+% for a total gain of 6.5%. These cumulative benefits arise when we create policies that support keeping forest land as forest land, by supporting landowner efforts at maintaining forest health, capturing mortality when it occurs, and ensuring the infrastructure to process periodic harvests remains intact.

Long Term Offtake Agreements

An offtake agreement allows carbon credit purchasers to buy credits now at a set price, with delivery to occur at some future date. This mechanism locks in a reasonable price for the buyer and provides up-front capital for the seller to implement the practices necessary to sequester more carbon. This type of agreement is common in the renewable energy sector which uses power purchase agreements to fund project development.

"The Family Forest Carbon Program is employing long-term offtake agreements to help scale its work to provide more family forest owners with carbon market opportunities. Already companies have committed to our verified credits via these agreements, and we anticipate others in the future."[22] This allows the FFCP to pay landowners to implement climate smart forestry practices that will generate future credits, but the landowner gets paid for the effort up front. The FFCP obtains the credit (additional carbon sequestered) after the practice yields its benefit.

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[22] FFCP Long term Offtake Agreements

Green Bonds

Green bonds are specialized financial instruments designed to fund projects with environmental benefits, such as renewable energy installations and the generation of nature-based carbon credits[23]. When investors buy green bonds, they are essentially lending money that is earmarked for these environmentally focused projects. The issuers of green bonds promise to repay the investment with interest, making them attractive not just for their environmental impact but also as a financial product.

The growth of the green bond market has been substantial. It began in 2007 and has seen a significant increase in issuance over the years, reflecting a growing interest from both public entities and private corporations in funding sustainability projects. This interest is driven by the dual benefits of contributing to environmental goals and receiving financial returns.

States are increasingly using green bonds as a mechanism to finance natural climate solutions. These bonds raise capital for projects that address climate change and environmental restoration, including forest conservation, watershed restoration, and the development of green infrastructure.

In 2022, the Family Forest Impact Foundation, affiliated with the American Forest Foundation, issued a $10 million green bond with Morgan Stanley as the underwriter[24]. This initiative was specifically designed to support the Family Forest Carbon Program, marking a significant effort to connect family forest owners to carbon markets. The program focuses on enabling these owners to engage in sustainable forestry practices that enhance carbon removal and storage, thereby generating additional income through the sale of carbon credits. This green bond aims to address a significant barrier for many family forest owners: the substantial upfront capital usually required to participate in carbon projects. By providing funding, the bond helps these owners manage their forests in environmentally beneficial ways and participate in the growing carbon credit market, ultimately contributing to climate change mitigation efforts.

The bond also prioritizes supporting underserved and underrepresented landowner groups, enhancing equitable access to carbon markets. This approach not only helps in fighting climate change but also in supporting the economic stability of these family forest owners. The success of this bond is underpinned by the verification of carbon sequestration improvements and the alignment with global green bond principles, ensuring the bond's proceeds are used effectively and transparently.

These public and private financed tools are crucial for meeting the large-scale financing needs required to address climate change and achieve sustainable development goals. As the market for green bonds expands, it continues to provide a viable pathway for significant investment in the transition to a greener economy. We recommend that Washington adopt the use of green bonds to finance investments in climate smart forestry and to underwrite programs like the Family Forest Carbon Program expansion into Washington that will serve small forest landowners.

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[23] Green Bonds (worldbank.org)

[24] First-of-Its-Kind $10M Green Bond Issued to Finance Family Forest Carbon Program to Fight Climate Change | American Forest Foundation

Green Banks

In the U.S., several states have been pioneering the use of green banks to finance natural climate solutions, leveraging public and private funds to support environmental projects that otherwise might not find financing in traditional markets[25]. Green banks are designed to reduce the financial risk of green projects by providing low-interest loans, grants, and other financial mechanisms. This approach helps to mobilize private sector capital to fund projects that mitigate climate change, support renewable energy, and conserve natural resources.

For example, Connecticut's Green Bank, the first of its kind in the nation, has been instrumental in driving investments in energy efficiency and renewable energy projects within the state. Similarly, the New York Green Bank focuses on reducing greenhouse gas emissions by investing in sustainable infrastructure and clean technologies. Although not technically a green bank, California's Climate Investments program uses cap-and-trade dollars to fund green projects, including forest management and urban greening, demonstrating a broader application of green bank principles.

These initiatives typically support projects such as forest restoration, agricultural best practices for carbon capture, and urban greening efforts that enhance resilience to climate impacts. By reducing the initial investment hurdles, green banks play a crucial role in accelerating the implementation of sustainable practices that lead to long-term environmental and economic benefits. This innovative financing model is becoming a blueprint for how states can effectively use financial tools to address climate change and promote sustainability at the local level. Our recommendation is that Washington adopt this innovative financing model by creating a quasi-public green bank supported with $100 million in public capital to finance climate mitigation initiative, with a focus on small forest landowners. Specific details on formation are provided in the recommendations section.

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[25] 2021AnnualIndustryReportFinal.pdf (dcgreenbank.com)

Figure 24 depicts how a state green bank funds and benefits flow. Figure 25 and Figure 26 present options for financing a state green bank. These concepts and figures were developed by Gordian Knot Strategies.
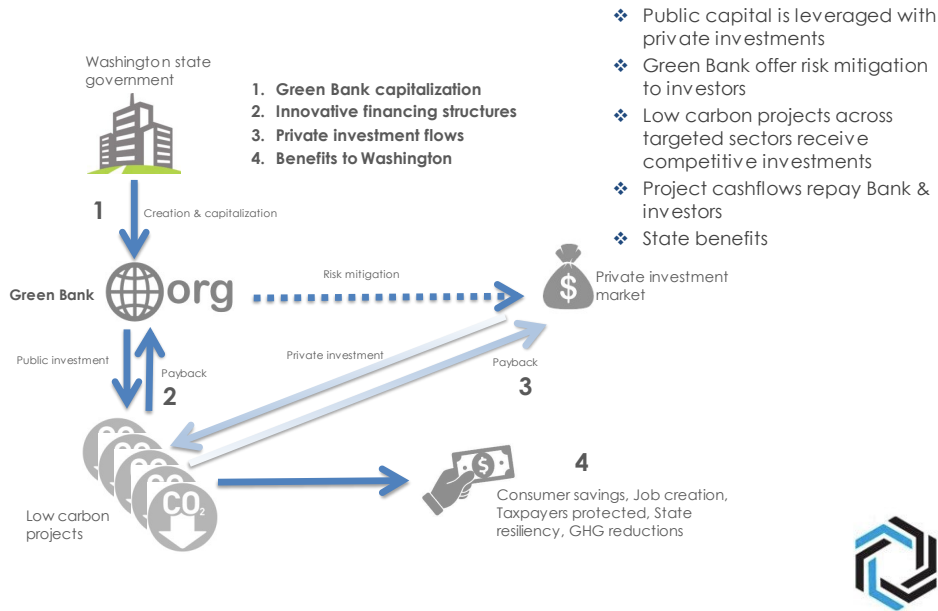
Figure 24: State Green Bank Fund and Benefit Flow

Option: State Green Bank financed by green bonds backed by the State

* State issues a green bond
* Bond proceeds finance the Bank
* Bank makes investments
* Projects repay the Bank
* Bank repays the bond holders
* Private investment capital leveraged to increase investment flows
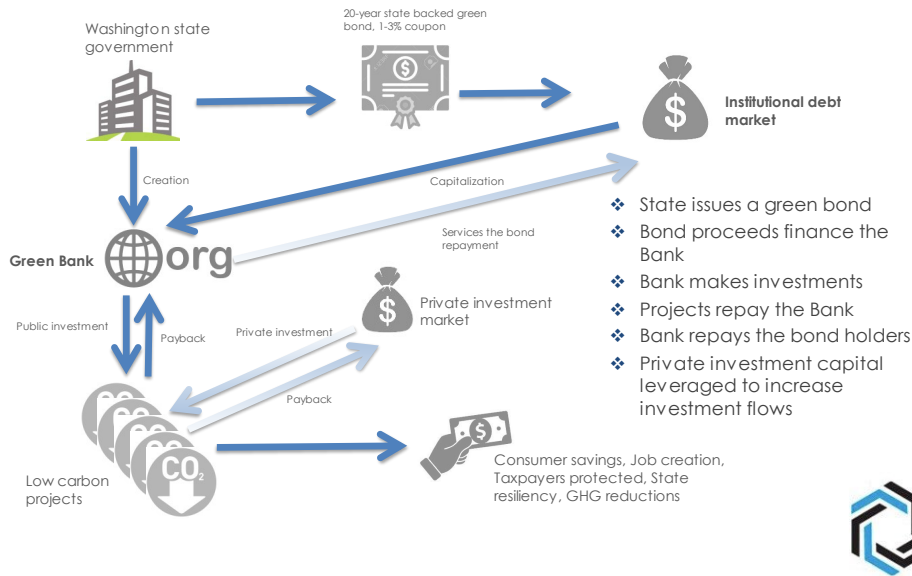
Figure 25: State Green Bank financed by green bonds backed by the state.

Option: State Green Bank financed by green bonds backed by the Clean Water SRF at Dept of Ecology

Title VI of the Water Quality Act, Paragraph (3): Authorizes SRFs "to guarantee, or purchase insurance for, local obligations where such action would improve credit market access or reduce interest rates."

* Green Bank issues the bond
* Bond guaranteed by SRF
* Bond sale proceeds capitalize the Bank
* Projects repay Bank and private investors
* Bank repays bond holders
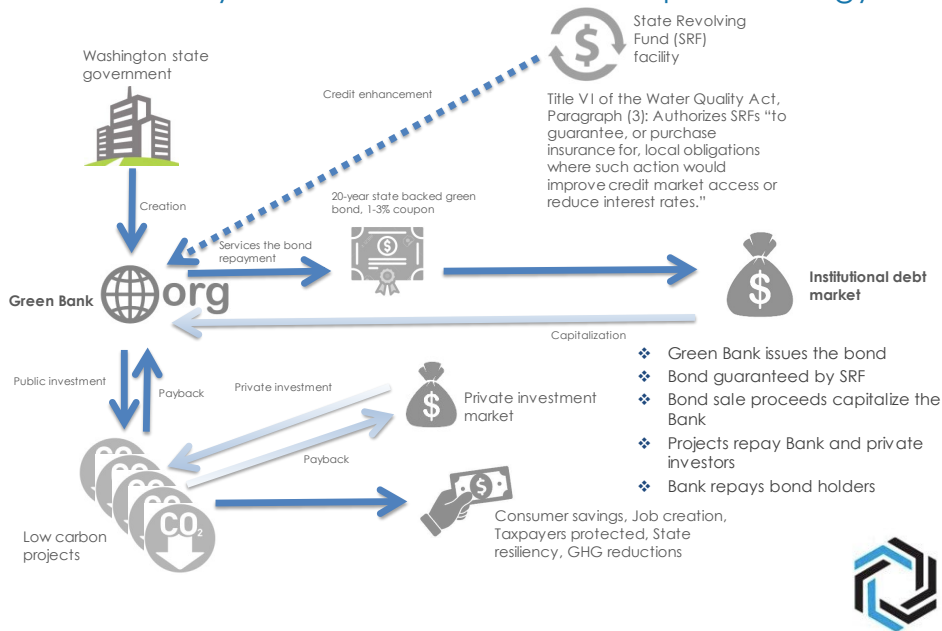
Figure 26: Green Bank financed by green bonds backed by the Clean Water SRF at the Department of Ecology.

DETAILED RECOMMENDATIONS

Figure 2 identifies the technical, protocol, financial, and participation levers that collectively are required to implement carbon market or carbon incentive policies in Washington state. Our analysis of the levers led to the following recommendations, that together will address the core requirements of the CCA legislative request.

Washington Forest Offset Protocols

To address the barriers and impediments for small forest landowner engagement in Washington's regulated market we recommend the Washington Department of Ecology revise Washington's Forest Offset Protocol (FOP) to simplify participation requirements, include less restrictive forest management practices, and shorten the required project period for small forest landowners.

This recommendation will be carried forward to the current FOP revision working group that will convene starting July 2024 given that at least one member of the CWG has been chosen to participate in that group.

Programmatic Support for Ongoing Technical Tool Development

Dedicated programmatic funding for ongoing statewide assessment and monitoring of forest conditions and land use change is needed. For the past 20 years the NRSIG at UW has been 100% soft funded through a variety of short-term, product specific contracts. They have delivered literally millions of dollars of benefits to the state in the process of generating those deliverables. Currently funded efforts at the Washington State Department of Natural Resources are limited to state lands and statewide assessments are sporadically funded, inconsistent, and inadequate for cap-and-trade carbon markets. It makes no sense to continue this haphazard support of one of the best products in the country. There are a few different models for how this recommendation could be implemented including:

4. Create legislation that enables the UW Precision Forestry Cooperative - which houses NRSIG - to be a Cost Center, much like CINTRAFOR (http://www.cintrafor.org/ - RCW 76.56). This would facilitate establishing a pathway for programmatic, legislatively dedicated funding for advancing these data products and tools.
5. Establish a new independent UW or collaborative higher-ed/agency organization to advance this work using a mechanism like the Advanced Technology Initiative that began the Precision Forestry Cooperative.
6. Establish a Public Benefit Corporation, starting with public support via a block grant to advance this work in a transparent and open way.

Of all these options, we believe the first one will deliver the most value to the state. It will also create the most respected and transparent data for carbon market transactions, and over the long term maintain Washington's lead in product development and artificial intelligence in using remote sensing to answer our most vital natural resource questions.

Specific Near-Term Tool Development Products

Datasets derived from digital aerial photogrammetry of NAIP images will become a foundational input to research and analysis of Washington forests. It has a higher spatial resolution than satellite imagery and the high temporal resolution (2 years between image acquisition) necessary to monitor forest disturbances and track growth. Remotely sensed forest inventory is approaching accuracies that allow for site specific assessments rather than regional trends. Model errors are larger than we would like (TPA +- 76; QMD +- 4 inches; Biomass +- 50 tons) but opportunities exist for continued improvement. Research is necessary to determine how best to utilize DAP in general and specifically related to a forest carbon program. We recommend funding for:

1. The production of statewide forest composition and structure raster datasets from future DAP acquisitions. Continued funding is necessary to produce these models as NAIP imagery is acquired at a 2-year interval.

2. The production of an updated Forestland Database of parcels, ideally at a frequency that matches NAIP acquisitions (2-year interval). The Forestland Database is the sole source of small forest landowner information available and the definitive source of forest conversion data in Washington state. Pairing frequently updated, DAP-based forest composition and structure estimates with concurrent parcel data would greatly enhance the States ability to quantify forest change related to conversion, management activities, disturbance events, and changing productivity. Each of these have significant impacts on forest carbon sequestration and storage.

3. A study on the stability of DAP-based predictions over time. This study demonstrated improved accuracy in predictions for validation stands (3 to 150 acres) compared to plots (.1 to .25 acre). It is necessary to determine at what spatial and temporal scales we can have confidence to detect real change in sequential predictions.

4. A study on leveraging repeated DAP measurements to improve stability in predictions. Error is present in DAP height estimates due to issues such as light condition at time of image acquisition and pixel off nadir angle. A sequence of DAP measurements can be used to smooth predictions and identify and correct errors, resulting in more stable estimates of forest growth and change.

5. A study on the use of deep learning models to predict forest composition and structure. Neural nets consistently show improved accuracies over other techniques for a wide range of problems. This topic has the potential for an extended line of research including the use of recurrent convolutional neural networks to leverage time series for satellite and DAP datasets to improve predictions. This study should fund a PhD student or post-doctorate position with expertise in artificial intelligence. Challenges include the need to overcome FIA use limitations due to confidentiality requirements.

6. A study on methodologies to satisfy FIA confidentiality requirements while allowing an attributed plot dataset to be used in a cloud computing environment such as Google Earth Engine. Current FIA use limitations add significant expense to research projects and limit the quality of the results. Methods have been outlined to overcome this challenge. A study should be funded to determine if these methods satisfy the FIA program, allowing

modeling products to be made public. It would also allow the Plot Database to be available for researchers.

7. A study on the advantages and drawbacks of using a geospatial baseline instead of a dynamic plot baseline for quantifying carbon additionality for a project. The protocol developed by Verra used the 10 most similar FIA plots to determine a business-as-usual alternative against which to compare project activities. This study identified issues with this approach including a scarcity of plots from the private owner class and an element of chance in the baseline events for any particular project due to the small number of plots used. DAP-based carbon estimates represent a census of growth, management activities, and disturbance events against which a project could be compared. The implications of this alternative approach and how best to ensure its adoption in carbon protocols should be investigated.

8. Updated resource assessments (timber/biomass supply study, forest conversion risk study, etc.) for Washington state.

9. A study to investigate unintended consequences of carbon markets specifically, is needed. Perceived benefits associated with no-action or delayed action management regimes may be offset by a slew of unintended consequences including increased emissions associated with future harvests due to sparse mill infrastructure, a lack of workforce due to decreased harvest activity, increased fire risk associated with a changing climate, and loss of the forest land base due to economic pressures from decreased timber value from all of the above.

10. Ensuring access to frequent direct forest measurements such as DAP should be a priority for the legislature on behalf of Washington's natural resource management agencies and academic researchers. The National Agriculture Imagery Program Digital Aerial Photogrammetrically (NAIP DAP) derived point clouds have proven valuable in improving remotely sensed structure models. The State should invest in NAIP DAP acquisition from the US Governments vendor. Coordinating this purchase with the US Forest Service may be beneficial. Without access to the DAP data, analyses will be no better than those done by commercial vendors that cater to the corporate voluntary carbon markets which have been the subject of multiple newsworthy investigations into their "real, permanent, quantifiable, verifiable, and enforceable" offsets.

Programmatic Support for Landowner Engagement and Community Building

Despite the many resources available in the state to support SFLO, including help from Washington DNR, Conservation Districts, NRCS and WSU Forestry Extension, the message is not getting out there, or the one that is received is of total confusion. State and federal agencies are tasked with providing a broad spectrum of resources to SFLO that may include, but are not focused on, engaging landowners in carbon smart practices or market programs.

Data from engaged landowners finds they are willing to participate in the carbon market and incentive space, but for the most part SFLO don't know what to do, where to start, who to trust, or if they can afford the time, energy, and effort it will take to implement the necessary changes on their forest land. They want to 'grow community' so they can feel supported as they embark on their journey of becoming part of a Community of Practice[26] centered on carbon smart forestry.

To address these barriers, impediments and gaps, we recommend that the Washington State Legislature provide funds, through a block grant from the Washington Department of Natural Resources or the Department of Commerce, to a Washington non-profit operated under the direction of small forest landowners. This block grant would be used to create and operate a robust technical and market support program for small forest landowners where they can learn with a community of their peers as they engage in providing critical climate mitigation services in the voluntary carbon market and carbon incentives space. The program would be designed to:

Serve as the vehicle for establishing a franchise of the American Forest Foundation's Family Forest Carbon Program (FFCP) in Washington.

    a) Develop and Maintain MOU with FFCP

    b) Develop proposed practices and standards that reflect the technologies and science NRSIG brings to the table and shepherd them through the standards development process.

    c) Develop proposed practices and standards that support climate smart fire resilient forests and include the carbon storage potential of biochar created from residues.

    d) Outreach/engagement to attract willing participants

    e) Aggregation tracking and coordination

Build a Community of Practice Centered on Climate Smart Forestry.

    f) This would include developing and piloting an "Apprenticeship-to-Ownership" program that would connect older SFLO who have no heirs with young people (prioritized from marginalized communities) who demonstrate a commitment to forestry. A potential pathway for demonstrating commitment would be completion of 1-2 years of paid, climate smart forest management work on participating SFLO properties, including technical training in silviculture and forest ecology. Graduating apprentices would be certified to join a pool of candidates matched to retiring landowners. We envision a range of pathways to ownership, including but not limited to a "work-to-own" track; access to low interest loans; and, in some cases, no or low-cost land transfers.

    g) Develop a pilot scale technical work force capable of conducting the work needed to implement climate smart forestry practices while also supporting apprenticeship and

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[26] Thinking Together: What makes Communities of Practice Work

forest matching (see below) goals. Organizations like Washington's own US Rake Force and AmeriCorps are models for what we envision as teams of technically trained forestry workers who could be paid with carbon incentive dollars (leveraged with additional funding) to complete climate smart forestry practices prescribed by the navigator service. This labor force would include young people participating in our "apprenticeship-to-ownership" program.

h) We recommend the creation of one or more working forest land trusts in Washington. Part of their mission would include facilitating and monitoring working forest land transfers to young people certified to manage them through the Apprentice-to-Ownership Program.

i) We also recommend developing a matching service (ForestMatch.org?) to build out a network of connections between landowners who have no heirs and young people who have the skills, desire, and energy to complete the labor for work-experience and linkages to sustainable land management. Extant examples include the WWOOF program for organic agriculture.

j) We recommend developing regional resource-sharing platforms and cooperative management groups.

Build engagement with non-traditional and underserved communities.

k) We have very limited information on existing SFLOs from marginalized populations. Our understanding would be greatly enhanced by gathering in-depth interviews of their lived experience, their needs, and their interest in participating in carbon programs in Washington. In particular, very little is known about the goals, ambitions, and limitations facing allotment owners in tribal communities. They should be prioritized in this work.

l) Exposure to the many facets of forestry and its associated job opportunities is a necessary part of building interest in both workforce development and forest ownership. We recommend identifying and funding opportunities to enhance outreach to schools (grades 7-12) by agency, nonprofit, and private sector employers in forestry, especially in geographic locations where underserved youth are concentrated. We anticipate working closely with the Pacific Education Institute YESS (Youth Engaged in Sustainable Systems) as a near term pathway.

m) Community-based cooperatives may offer opportunities for groups of marginalized people to become SFLOs, but additional research is needed to identify a pragmatic pathway. Potential models for study might include the U.S Forest Service Community Forest Program, as well as community equity trusts, which are collectively managed and owned projects that allow participants to build wealth, much in the same way that Real Estate Investment Trusts (REITs) own / operate income-producing real estate on behalf of investors. Models such as the Montesano Community Forest which provides tangible return on investment are the preferred model.

Educating and training for small forest landowners on carbon mitigation and offset programs.

Providing peer-to-peer mentorship through a navigator service to build landowner capacity in accessing financial, technical, and implementation support.

> One of the CWG highest-ranking recommendations is the creation of a statewide system of navigators who will work as "forest diplomats" to identify and facilitate funding opportunities for carbon storage, fire resilience, and forest health. An an example, the Maine Woodland Owners Association has partnered with the Natural Resources Conservation Service (NRCS) to create a similar position paid for three years, with a possible two-year extension. The primary role of MWO's "navigator" will be to help small forest landowners qualify for participation in NRCS programs, in part by taking on the often confusing and time-consuming tasks of applying for funds to support management plans and practices like thinning and invasive weed removal.

Establishing a Washington partner to coordinate linkages needed to galvanize and support SFLO engagement in carbon markets and incentive programs.

n) Work with SFLO and potential carbon market developers to support fair and equitable market entrance.

o) Work with SFLO, and state and federal agencies to address specific social barriers to entry into carbon market and incentive programs. This includes, but is not limited to:

  i) Additional EFR on underrepresented populations with a focus on environmental justice, diversity, equity, and inclusion to ensure equitable participation.

  ii) Behavioral Insights: Apply behavioral science to design effective incentives and communication strategies.

Cooperate with forestry technical service providers, including agencies with well-established technical and financial offerings.

Financial Investment Tools for Climate Smart Forestry

We recommend that Washington state develop innovative pathways to finance investments in climate smart forestry practices targeted at small forest landowners. These include incentives directly to landowners, as well as the use of green bonds and the creation of a green bank.

Practice Incentives and Program Modifications

There are many existing programs that support improved forest management on SFLO lands. While not an exhaustive list, these programs could be implemented or modified to focus on carbon sequestration:

1) Cost share for planting, improvements, and lease for maintenance period: USDA NRCS – CRP/EQIP; AFF-F2F

2) Payment for improved management practices to increase carbon: AFF Family Forest Carbon Program (FFCP)

3) Compensation for economic/opportunity cost of extending harvest rotation: Finite Carbon, other voluntary carbon market providers

4) Watershed/landscape-scale integrated incentives: Chehalis Basin Aquatic Species Restoration Plan (ASRP)

5) Timber easement for legacy (unharvested) stands: WA State DNR - Forest Riparian Easement Program (FREP)

6) Conservation easements and purchase of development rights: The Nature Conservancy (TNC), Forterra

7) Public Benefit Rating System (PBRS) adjustments to account for carbon sequestration as a fungible benefit that could be converted to land tax reductions.

8) Payments for wildfire risk reduction and disaster preparedness, including a focus on generating place-based biochar from land management activities.

9) Reconciliation of regulatory hurdles to implementation with carbon smart goals, including implementation of activities on sensitive sites using adaptive management principles.

Financial Incentives

1) Offer loan or bond guarantees to reduce the cost of capital financing forest carbon projects that require patient capital recovery, including reforestation, fire risk reduction, and improved forest management carbon projects. Qualified forest carbon projects would be required to use a methodology approved by a credible, third-party entity, as determined by the Department of Ecology.

2) Offer grants to small forest landowners that will assist in covering a portion of the upfront costs of developing a forest carbon project, such as the cost of a carbon inventory and third-party verification.

3) Create a state insurance product or a state buffer pool for use by the private carbon marketplace as an alternative to depositing a portion of project carbon credits into a registry buffer pool account.

Green Bonds

Washington should adopt the use of green bonds to finance investments in climate smart forestry and to underwrite programs like the Family Forest Carbon Program expansion into Washington that will serve small forest landowners.

Green Bank

Washington should create a quasi-public green bank supported with $100 million in public capital to finance climate mitigation initiative, with a focus on small forest landowners.

1) Green bank oversight from an appointed Board of Directors
2) Capitalize with $100 million in public funds, which can leverage $500 million in private capital
3) State should use several funding sources, including green bonds, the state climate investment fund, the state clean water revolving fund, and the state clean energy fund
4) Legislation will be needed to create the entity, and possibly regulations to access certain forms of funding
5) The Green Bank will need to hire dedicated staff, borrowing some administrative services from other agencies (Department of Ecology, Department of Commerce) at start-up
6) Green Bank should offer a portfolio of financing and market development solutions, focused on initiatives that demonstrate a positive climate impact, a positive environmental justice impact, the ability to service low-interest repayments to the Bank, and direct positive impact for the state

Visual representations of flow of benefits for state green bank funds and potential funding models are show in Figures 27-29. These concepts and figures were developed by Gordian Knot Strategies.

State Green Bank can drive public-private investments in the low carbon economy & reduce GHGs

❖ Public capital is leveraged with private investments
❖ Green Bank offer risk mitigation to investors
❖ Low carbon projects across targeted sectors receive competitive investments
❖ Project cashflows repay Bank & investors
❖ State benefits

1. **Green Bank capitalization**
2. **Innovative financing structures**
3. **Private investment flows**
4. **Benefits to Washington**
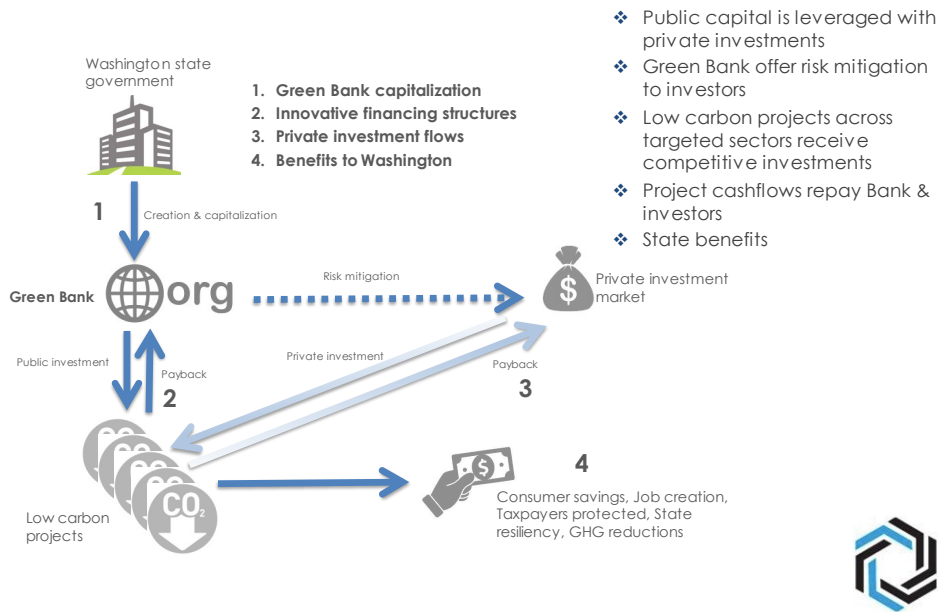
Figure 27: State Green Bank Fund and Benefit Flow

Option: State Green Bank financed by green bonds backed by the State

❖ State issues a green bond
❖ Bond proceeds finance the Bank
❖ Bank makes investments
❖ Projects repay the Bank
❖ Bank repays the bond holders
❖ Private investment capital leveraged to increase investment flows
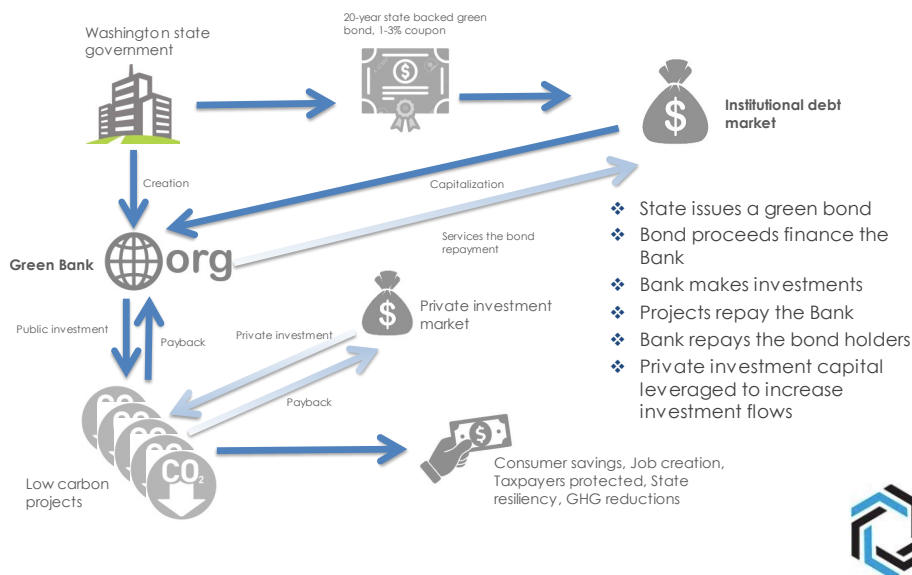
Figure 28: State Green Bank financed by green bonds backed by the state.

Option: State Green Bank financed by green bonds backed by the Clean Water SRF at Dept of Ecology

State Revolving Fund (SRF) facility

Title VI of the Water Quality Act, Paragraph (3): Authorizes SRFs "to guarantee, or purchase insurance for, local obligations where such action would improve credit market access or reduce interest rates."

Washington state government

Credit enhancement

Creation

20-year state backed green bond, 1-3% coupon

Services the bond repayment

Green Bank .org

Institutional debt market

Capitalization

- ❖ Green Bank issues the bond
- ❖ Bond guaranteed by SRF
- ❖ Bond sale proceeds capitalize the Bank
- ❖ Projects repay Bank and private investors
- ❖ Bank repays bond holders

Public investment

Payback

Private investment

Private investment market

Payback

Low carbon projects

CO₂

Consumer savings, Job creation, Taxpayers protected, State resiliency, GHG reductions

Figure 29: Green Bank financed by green bonds backed by the Clean Water SRF at the Department of Ecology.

Appendix 1

DEVELOPING SMALL FOREST LANDOWNER CARBON ASSESSMENT AND MONITORING TOOLS

Luke Rogers
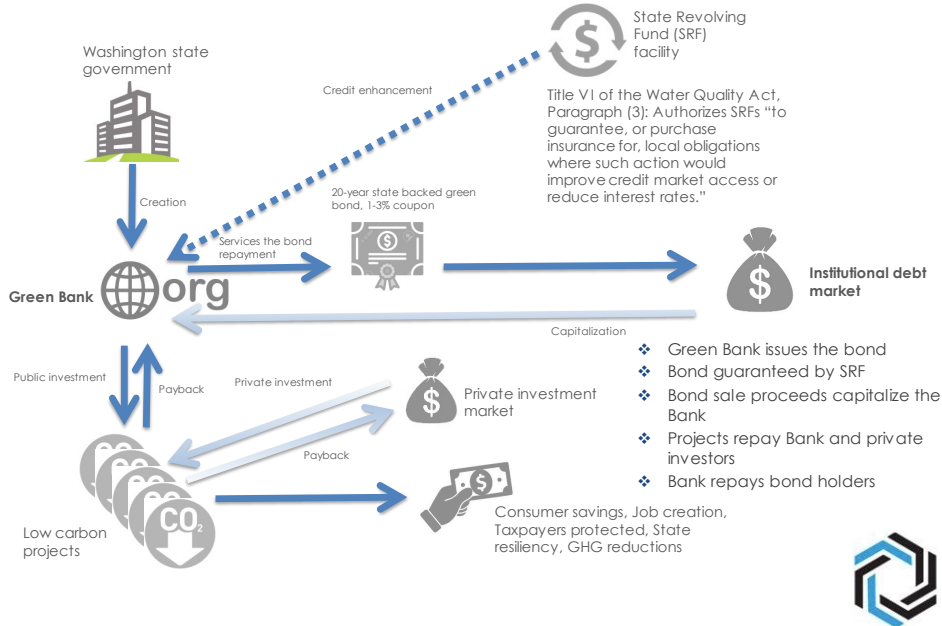Andrew Cooke
Jeffrey Comnick

W NRSIG

Natural Resources Spatial Informatics Group
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June 18, 2024

CONTENTS

1 INTRODUCTION

The Washington state Cap-and-Invest program is developing rules to provide payments to forest owners for storing carbon. Protocols used in California have been identified as a starting point for this program. Research indicates developing a carbon offset program is difficult and likely to result in overestimation of carbon credits (for example, see Badgley et al. 2022; Greenfield 2023; and West et al. 2023). Conceptually, the carbon emissions and storage associated with forest management for a proposed project is compared against an alternative management regime, with verified positive carbon credits eligible for payment. The Verra Verified Carbon Standards program includes an alternative approach. The Verra protocol for improved forest management (Shoch et al. 2022) (VM00045) compares project carbon against matched forest inventory plots from programs such as the US Forest Service Forest Inventory and Analysis program (McRoberts et al. 2005). Other forest carbon programs exist including the American Carbon Registry (Krapfl et al. 2021).

To participate in these programs, project carbon must be quantified using new field plots. The cost of installing these plots has been prohibitively expensive for small forest landowners (SFLO). Newly available datasets including digital aerial photogrammetry (DAP) from the National Agricultural Imagery Program (NAIP) suggest that it may be possible to replace field plots with remotely sensed forest inventory ("National Agriculture Imagery Program - NAIP Hub Site" 2023). This approach develops wall-to-wall predictions of forest composition and structure by developing statistical models from physical, climate, spectral, and photogrammetric datasets along with geolocated field plots.

In this project, we investigated the potential to use remote sensing forest inventory for a carbon program. First, we developed a comprehensive database of forest inventory field plots from the Washington Department of Natural Resources (DNR) and the US Forest Service (USFS). For each plot, we summarized tree records to calculate species proportion and structure attributes on a per acre basis, including forest biomass. We processed digital elevation models, climate layers, satellite imagery, and NAIP-derived DAP. We attributed field plots with over 300 predictor variables. We then developed models to predict each response variable and produced statewide rasters at 66-foot resolution. We report the accuracies of these models at two spatial scales.

Second, we used the new prediction rasters and parcels from the Forestland Database to develop improved estimates of SFLO forest attributes (Rogers, Cooke, and Comnick 2023). We summarized carbon in SFLO forests and compared the estimates from FIA. We contrasted the average forest structure attributes for SFLO against other major owner classes. We classified SFLO forest acres for several species, density, and size classes to identify opportunities for improved forest management.

Third, we applied our models in a demonstration tool for a theoretical forest carbon program. We selected the Verra improved forest management protocol to demonstrate how the program could work. While there are other standards and protocols for greenhouse gas reduction and offset projects, recent updates to the Verra protocol by the American Forest Foundation and The Nature Conservancy resulted in the newly minted Family Forest Carbon Program, which was identified by the Family Forest Carbon Working Group as a promising starting point for Washington State small forest landowner engagement in carbon cap-and-trade markets. The Verra program compares actual growth and harvest activities for a project against matched plots over time. Here, we simulated treatments for the project and baseline plots using the Forest Vegetation Simulator (Crookston and Dixon 2005). We report issues that were

identified while developing the demonstration tool and describe opportunities to improve carbon accounting. Finally, we list recommendations based on our study.

2 FOREST COMPOSITION AND STRUCTURE MODELING

2.1 PLOT DATABASE

2.1.1 Field Plot Sources

We developed a comprehensive database of field plots (Plot Database) from state and federal sources. The largest source of plots came from FIA. We also included plots from:

1) USFS Region 6 LIDAR Biometric research areas in the Colville, Gifford Pinchot and Mount Baker-Snoqualmie, and Okanogan-Wenatchee National Forests
2) DNR Remote Sensing Forest Resource Inventory System (RS-FRIS)
3) DNR research areas in the Ahtanum watershed
4) DNR research areas in northeast Washington
5) University of Washington riparian study areas in the Mashel watershed.

All plots used fixed area sampling, though plot sizes varied. Standard tree measurements were taken on each plot.

2.1.2 Plot Inventory Summary Calculations

The Plot Database includes attributes for each plot summarized to a per acre value. Using a minimum tree diameter of four inches, we calculated trees per acre (TPA_GE4), basal area per acre (BAA_GE4), and quadratic mean diameter (QMD_GE4). We also calculated the basal area weighted height of the largest 40 trees per acre by diameter (Ht_Top40), relative stand density index (RSDI), and total live biomass above and below ground (TLBM).

To calculate relative stand density index, we first calculated Reineke's stand density index (Reineke 1933). Next, we calculated a maximum stand density index (MaxSDI) for each plot. Woodall and Weiskittel (C. W. Woodall and Weiskittel 2021) recently developed MaxSDI values by forest type (specific to ecoregion and dominant species) but did not account for mixed species stands. Woodall, Miles, and Vissage (2005) developed a model to estimate MaxSDI in mixed species stands using species specific gravity and basal area proportion. Here, we used the equation by Woodall, Miles, and Vissage to calculate species weights. We then calculated MaxSDI for each plot by multiplying the species weights by the MaxSDI from the matching forest type. Finally, we calculated RSDI by dividing the relative stand density index by the MaxSDI for each plot.

We calculated total above ground forest biomass using national biomass estimators (Jenkins et al. 2003) and the component ratio method (Christopher W. Woodall et al. 2011). For this analysis, we summarized the total live biomass in above- and belowground tree components. Unlike VM00045, we did not calculate biomass in snags or downed woody debris. We also did not summarize biomass in litter or soil. This differs from FIA and must be considered when making comparisons. We assumed a multiplier of 0.5 to convert biomass and carbon.

2.2 PREDICTOR VARIABLE RASTER CREATION

We created statewide rasters for each potential predictor variable. This was necessary to attribute the field plots and to make the final prediction rasters using the selected models. Over 500 statewide rasters were produced at a 66-foot resolution. We used ESRI ArcGIS Pro for most of the spatial processing in this project (*ArcGIS Pro* (version 3.1.3) 2023).

We created a custom digital elevation model (DEM) for Washington State using DEM's from LIDAR acquisitions where possible ("Washington Lidar Portal," n.d.). We prioritized the best DEM where multiple acquisitions existed. Where no LIDAR acquisition was available, we used data from USGS 3DEP (U.S. Geological Survey 2017). We resampled the DEM mosaic to create a final DEM. We then calculated topographic rasters including slope, aspect, elevation, topographic position index (at multiple scales), topographic wetness index, and potential relative radiation.

We downloaded the Gridded National Soil Survey Geographic Database (gNATSGO) (Soil Survey Staff 2020) from the USDA Natural Resource Conservation Service (NRCS). gNATSGO provides numerous soil attributes including depth, pH, percent by soil particle size (sand, silt, and clay), and water holding capacity. We also obtained soil-climate layers from the Washington Department of Natural Resources including actual evapotranspiration and water deficit.

We used the ClimateNA (Wang et al. 2016) program to down-sample PRISM climate data (PRISM Climate Group 2014) using our 66-foot DEM. ClimateNA produces annual, seasonal, and monthly values for temperate, precipitation, relative humidity, growing days, and other climate related variables. For this analysis, we used annual and seasonal variables as predictors.

We used Google Earth Engine (Gorelick et al. 2017) to produce cloud- and snow-free composite images from Sentinel-2 top-of-atmosphere and surface reflectance imagery (Harmonized Sentinel-2 MSI: MultiSpectral Instrument, Level-2A Surface Reflectance) (ESA 2021). We created images by season for all years between 2016 and 2021. We also downloaded Continuous Change Detection and Classification (CCDC) rasters derived from Sentinel-2 for each season for all years between 2016 and 2021 (Gorelick et al. 2023).

We processed DAP datasets produced by DNR photogrammetrists from NAIP imagery for the years 2015 through 2021. We used the GridMetrics program from the US Forest Service Fusion software to produce the prediction rasters (McGaughey 2023). Fusion outputs a large number of statistics including percentile heights, percent cover, and height-distribution shape variables. Using our high-quality ground model in Fusion was important to obtain accurate vegetation height estimates.

2.3 PLOT PREDICTOR VARIABLE ATTRIBUTION

To attribute the field plots with the predictor variables, we first determined plot geometry based on geolocated center points and design descriptions. For simple fixed area plots this required buffering the plot center by the radius that corresponds to the plot size. FIA uses a grouped subplot design (Westfall et al. 2022). For each FIA plot, three subplots were equally spaced around a center subplot. Subplot locations were not always provided; if missing, we inferred the location from the plot center point and design. We then buffered the subplots to create the plot geometry.

We then intersected the plot geometry with the prediction rasters. We determined the most appropriate technique (e.g. bilinear interpolation, zonal mean) to summarize each variable. To summarize DAP, we used the Fusion CloudMetrics function. This approach clips the DAP point cloud data using the plot geometry and then calculates summarized height metrics. This differs from the GridMetrics function used to create the DAP rasters that will be used to make predictions with the fitted models. In the future, we plan to use GridMetrics for both steps.

Because FIA plots consist of subplots, we attributed them two ways. First, we calculated a single value for each full plot. Second, we calculated attribute values for each subplot. For this project, we considered the subplots to be independent observations.

2.4 MODEL FITTING

Next, we fit models to predict inventory summary attributes from the predictor variables. We divided Washington state into two modeling regions (east and west of the Cascade crest). Prior to modeling, we removed plots with significant differences between field values and DAP height or spectral values. We fit species proportion models for all species with presence on at least 100 plots in a model region. Table 1 lists the species we modeled in each region.

We evaluated four model forms for each response variable, including regression with elastic net regularization (Zou and Hastie 2005), Random Forest (Breiman 2001), nearest neighbor (Crookston and Finley 2007), and XGBoost (Chen and Guestrin 2016). We used the R software program for all statistical analysis (R Core Team 2021). Prior to model fitting, we withheld 10 percent of the plots for testing, stratifying on presence/absence for the species proportion models.

We used a modeling framework to identify optimal model parameters with cross-validation (Kuhn and Wickham 2020). Due to the large number of predictor variables, we were forced to develop a robust variable selection procedure to reduce the number of variables considered in the final fitting process. For Random Forest and XGBoost we ranked variables using variable importance scores. For regression and nearest neighbor, we ranked variables using the average R^2 from models fit on subsamples of predictor variables and observations. We then used forward selection to identify the best predictors. We used a stopping criteria based on improvement in R^2 to determine how many variables to include. The selected predictors were used in the modeling framework to determine final model fits.

Table 1. Tree species for which basal area proportion models were developed. Species codes from the USDA Natural Resources Conservation Service Plants Database are used throughout this report.

Plants Code	Common Name	Scientific Name	Modeled in Western WA	Modeled in Eastern WA
ABAM	Pacific silver fir	Abies amabilis	X	X
ABGR	grand fir	Abies grandis		X
ABLA	subalpine fir	Abies lasiocarpa	X	X
ABPR	noble fir	Abies procera	X	
ACMA3	bigleaf maple	Acer macrophyllum	X	
ALRU2	red alder	Alnus rubra	X	
BEPA	paper birch	Betula papyrifera		X
CHNO	Alaska yellow-cedar	Chamaecyparis nootkatensis	X	
LAOC	western larch	Larix occidentalis		X
PIAL	whitebark pine	Pinus albicaulis		X
PICO	lodgepole pine	Pinus contorta	X	X
PIEN	Englemann spruce	Picea engelmannii		X
PIMO3	western white pine	Pinus monticola	X	X
PIPO	ponderosa pine	Pinus ponderosa		X
PISI	Sitka spruce	Picea sitchensis	X	
POBAT	black cottonwood	Populus balsamifera	X	
POTR5	quaking aspen	Populus tremuloides		X
PSME	Douglas-fir	Pseudotsuga menziesii	X	X
QUGA4	Oregon white oak	Quercus garryana		X
THPL	western redcedar	Thuja plicata	X	X
TSHE	western hemlock	Tsuga heterophylla	X	X
TSME	Mountain hemlock	Tsuga mertensiana	X	X

2.5 VALIDATION STANDS

We assessed model performance at two levels: against the withheld plots and against validation stands. The validation stands were installed by the Washington Department of Natural Resources to evaluate remote sensing-based forest inventory models. They ranged in size from 3 acres to 150 acres. All but eight were located in western Washington. Multiple field plots were installed in each stand. For each plot, we calculated summary attributes from the sample tree records, then averaged the plot values for each validation stand.

We produced prediction rasters for each validation stand for each fitted model (Figure 1). We used the average value of all cells in a stand to represent a validation stand. The average predicted value
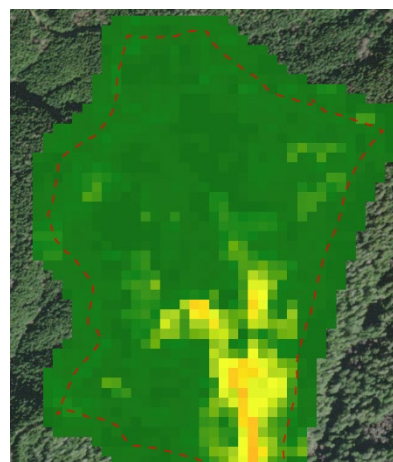
Figure 1. Example image of the predicted hardwood proportion raster for one validation stand.

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was compared to the averge validation stand value to calculate summary statistics.

2.6   MODEL ASSESSMENT

We generated a report for each model listing summary statistics at the withheld test plot and validation stand spatial scales. We calculated coefficient of determination (R^2), root mean squared error (RMSE), mean absolute deviation, bias, and Akaike information criterion (AIC). We created charts displaying model predictions versus field values and maps showing deviations from field values geographically. We also inspected model region prediction rasters to determine if broad geographic trends agreed with expectation. For example, Figure 2 shows hardwood proportion is highest near rivers on the Olympic Peninsula. In Figure 3, Douglas-fir (*Pseudotsuga menzeisii*) is the dominant species in the Puget Sound lowlands and southwest Washington, while western hemlock (*Tsuga heterophylla*) is predicted to be a dominant species on the western Olympic Peninsula and in the Cascade Mountains but a minor species in other regions of western Washington.

Figure 2. Predicted hardwood proportion on the Olympic Peninsula.

Douglas-fir Basal Area Proportion   **Western Hemlock Basal Area Proportion**
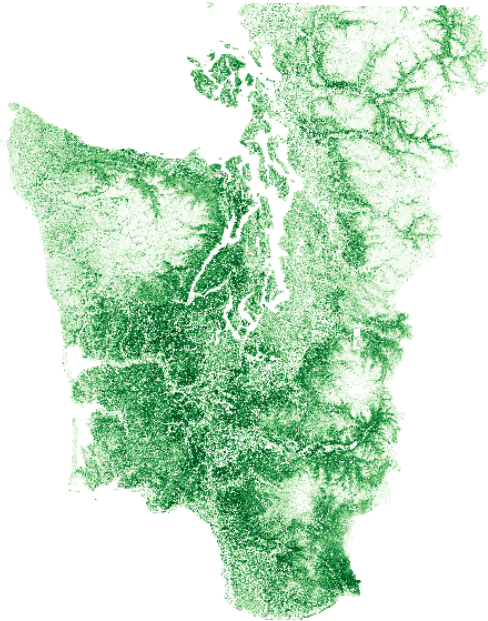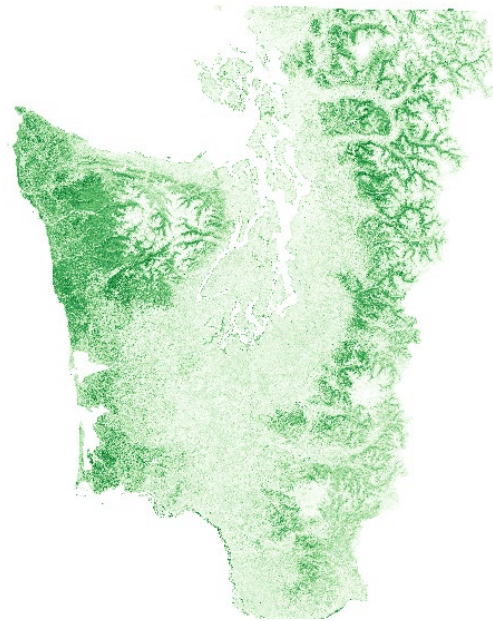
Figure 3.Predicted Douglas-fir (PSME) and western hemlock (TSHE) basal area proportion in Western Washington.

After reviewing the modeling results, we simplified our methodology by selecting XGBoost for all models. XGBoost was the best model by R^2 and RMSE for the majority of response variables, though other models were frequently competitive and occasionally better. XGBoost appeared to improve bias over other model forms, especially linear regression.

2.7 FOREST MODEL SUMMARY STATISTICS

Table 2 and Table 3 list the coefficients of determination (R^2) and root mean squared errors for species and structure models, respectively. For each model, statistics are reported for plots withheld while fitting the models and for validation stands. Blank values indicate species were not present in any validation stand. The results show that model accuracy generally improves as spatial scale increases.

The most accurate species model is hardwood proportion in both western and eastern Washington. Individual hardwood species models also perform well. Variables derived from spectral bands were the most important predictors for these response variables. Individual conifer species models are notably less accurate.

The height of the largest 40 trees per acre is the most accurate structure model. This is expected given vegetation height is a primary attribute from DAP processing. Other response variables correlated with height, such as basal area, quadratic mean diameter, total aboveground biomass, and volume are also relatively accurate. Models predicting trees per acre are the least accurate structure models.

Table 2. Summary statistics for forest structure models using withheld plots and validation stands.

		R^2		RMSE	
		Plot	Validation Stand	Plot	Validation Stand
West	TPA GE 4	0.23	0.53	211.5	76.3
	BAA GE 4	0.54	0.66	105.1	44.2
	QMD GE 4	0.58	0.52	4.3	3.8
	Height of Largest 40 TPA	0.86	0.82	14.1	13.2
	Board Foot Volume	0.61	0.68	29,946	12,869
	Cubic Foot Volume	0.6	0.7	4,734	2,055
	Total above ground biomass	0.64	0.72	103	43.8
	Relative stand density index	0.45	0.55	0.22	0.12
East	TPA GE 4	0.25	0.49	192.2	61.9
	BAA GE 4	0.52	0.76	67.8	22.3
	QMD GE 4	0.39	0.63	4.6	4.5
	Height of Largest 40 TPA	0.7	0.64	15.2	15.2
	Board Foot Volume	0.53	0.69	15,217	3,209
	Cubic Foot Volume	0.55	0.68	2,560	701
	Total above ground biomass	0.54	0.71	55.4	12.9
	Relative stand density index	0.41	0.83	0.23	0.09

Table 3. Summary statistics for species proportion models using withheld plots and validation stands.

		Number of Plots with Species Present	R^2		RMSE	
	Species		Plot	Validation Stand	Plot	Validation Stand
West	Hardwood Proportion		0.6	0.83	17.5	7.2
	ABAM	2457	0.42	0.64	18.9	4.5
	ABLA	333	0.53		8.7	
	ABPR	467	0.14	0.15	10.1	6
	ACMA3	545	0.28	0.53	10.8	4
	ALRU2	1649	0.33	0.75	18.2	6.8
	CHNO	277	0.15		5	
	PISI	234	0.08	0.11	4	3.9
	PICO	117	0.32		6.9	
	PIMO3	106	0.11	0.02	3.3	0.6
	POBAT	101	0.31	0.51	4.2	3.4
	PSME	5080	0.48	0.52	29.2	20.8
	THPL	1743	0.11	0.13	15.7	7.5
	TSHE	4970	0.35	0.54	25	15.6
	TSME	642	0.49		9.8	
East	Hardwood Proportion		0.56	0.39	10.1	2.5
	ABAM	550	0.51		10.7	
	ABGR	1623	0.24	0.44	18.4	10.7
	ABLA	1375	0.37	0.64	15.5	3
	BEPA	126	0.32		2.2	
	LAOC	1387	0.3	0.73	14.6	10.6
	PIEN	978	0.19	0.45	11.8	8
	PIAL	142	0.39	0.98	6.3	0.24
	PICO	1405	0.39	0.92	17.6	8
	PIMO3	217	0.02		3.1	
	PIPO	2080	0.45	0.95	24.9	9
	POTR5	107	0.25		5	
	PSME	4972	0.33	0.51	33	11.2
	QUGA4	125	0.71		5.2	
	THPL	812	0.28		11	
	TSHE	613	0.27		9.2	
	TSME	363	0.37		9.1	

2.8 Comparison of Models to Gradient Nearest Neighbor

To further evaluate our models, we compared our predictions (NRSIG) to those made by the Gradient Nearest Neighbor (GNN) model. The Landscape Ecology, Modeling, Mapping, and Analysis (LEMMA) research group pioneered the development of wall-to-wall forest estimates using field plots and remote sensing products. The most recent GNN model was published in 2017. GNN predictions are based on environmental variables and satellite imagery from three Landsat sensors (Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI) that have been processed through the Landscape Change Monitoring System (LCMS) (Housman, Campbell, and Finco 2021). This differs from our models which use higher resolution data from Sentinel-2. We also have direct measurements of forest structure from DAP. We expect to see improved model accuracies as a result. To determine this, we summarized the GNN predictions for each validation stand in western Washington and compared the predictions to our models.

Table 4 lists the summary statistics. Figure 4 and Figure 5 provide scatterplots comparing modeled values against the field values for structure and species attributes, respectively. Each point represents a validation stand. As expected, we found noticeable improvement in the model accuracies for all structure models, indicating the importance of DAP-derived predictor variables. We also found improvements in the hardwood proportion and Douglas-fir proportion models. Interestingly, we did not see improvement in predicting western hemlock proportion.

The GNN models were developed using a different minimum tree diameter (approximately 1 inch versus 4 inches) for including trees in the summary calculations (e.g. TPA, BAA, etc.) for our stands and the validation stands. For most attributes we assumed this to have minimum impact on the results. This is supported by the scatter plots not showing a consistent shift compared to our results. The trees per acre attribute was an exception. GNN predicted significantly more trees in the validation stands than our models and the field values. We did not consider comparisons with this model valid.

Table 4. Summary statistics comparing field values to predictions made by GNN and NRSIG models for validation stands in Western Washington.

	R^2		RMSE	
Attribute	GNN	NRSIG	GNN	NRSIG
Basal area per acre	0.308	0.662	63.2	44.2
Quadratic mean diameter	0.344	0.518	4.38	3.75
Top Height	0.44	0.824	23.5	13.2
Cubic foot volume per acre	0.413	0.702	2883	2055
Hardwood proportion	0.424	0.833	13.4	7.23
PSME Proportion	0.369	0.518	23.8	20.8
TSHE Proportion	0.546	0.54	15.5	15.6
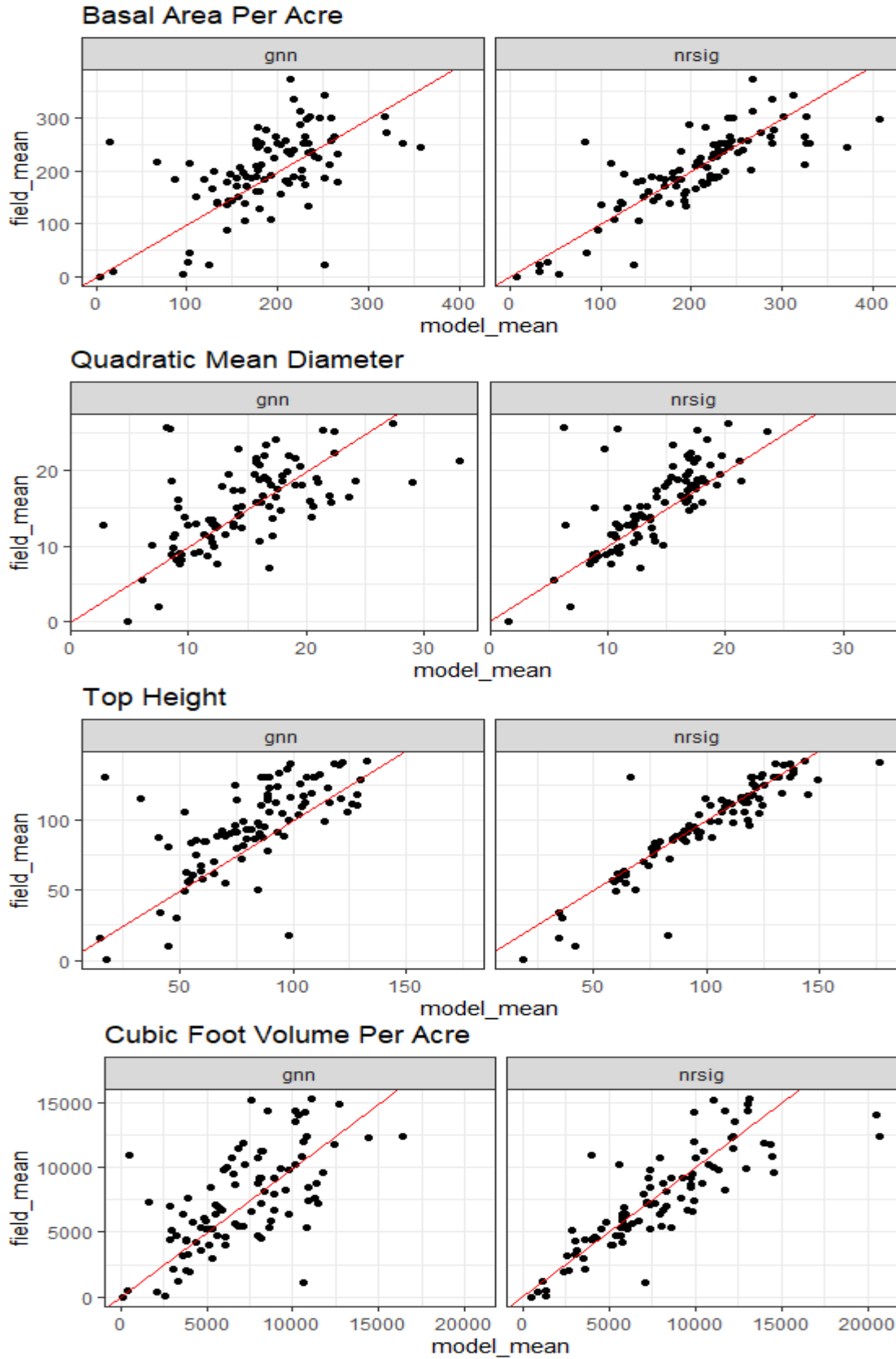
Figure 4. Comparison of structure predictions from GNN and NRSIG models for validation stands in Western Washington.
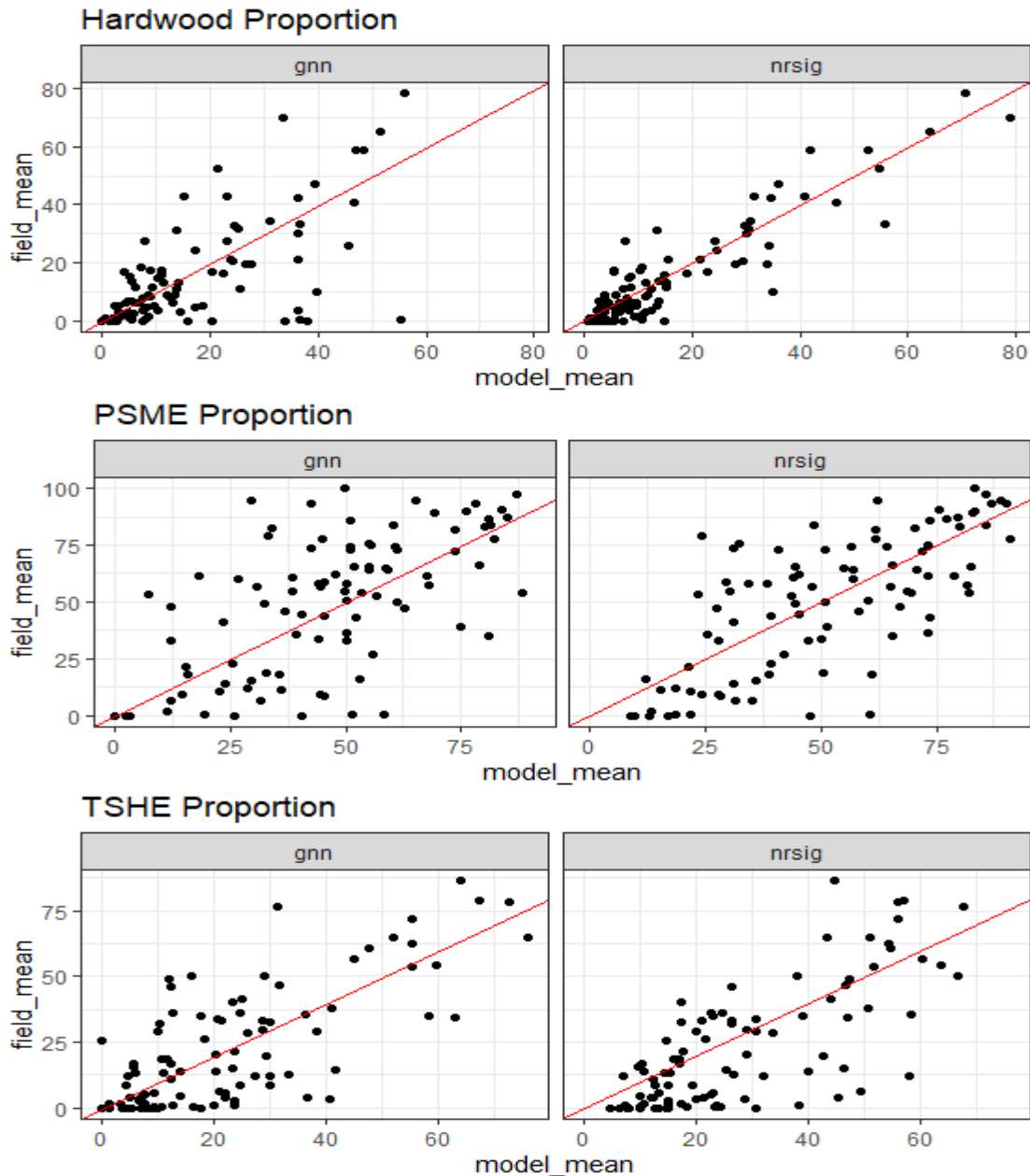
Figure 5. Comparison of species proportion predictions from GNN and NRSIG models for validation stands in Western Washington

2.9 OUTPUT RASTER CREATION

Using the fitted model for each response variable and model region, we produced statewide rasters at a 66-foot resolution. We used the Terra package for the R programming language to make the rasters (Hijmans 2023).

2.10 FORESTLAND DATABASE

Although the predicted forest species and structure rasters were produced statewide, for this project we were interested exclusively in SFLO forests. To identify ownership, we used the Forestland Database, a

comprehensive dataset of forested parcels in Washington state (Rogers, Cooke, and Comnick 2023). It was developed by normalizing parcel data from county assessors and state and federal agencies, then intersecting parcel boundaries with management zones (riparian and upland) and land cover datasets including the National Land Cover Dataset (U.S. Geological Survey 2021) and Gradient Nearest Neighbor (Ohmann and Gregory 2002). SFLO parcels were identified through a combination of owner name analysis (i.e. first classifying private industrial owners) and parcel and forest size requirements.

3   ANALYSIS OF SFLO FORESTS

Obtaining an accurate assessment of SFLO carbon and other attributes has been difficult for several reasons. First, publicly available FIA data does not differentiate between private owner classes for confidentiality reasons. Second, because FIA plot density is relatively low, filtering by owner class results in estimates with low confidence. This is especially true for small area estimation where plots are further filtered by geographic range. Prior wall-to-wall estimates of forest condition have not been accurate enough to be useful at a stand, parcel, or project scale. The forest structure models developed in this project, paired with owner classification from the Forestland Database, address these issues. An analysis of SFLO forests is provided as a case study, though each could be improved with additional resources.

The forest species and structure rasters were intersected with parcels identified as SFLO from the Forestland Database. We then summarized forest attributes for each parcel using the zonal summary tools in the Spatial Analyst extension for ArcGIS Pro. An overview of SFLO demographics is provided first, followed by a summary of forest carbon. Forest structure summaries are then used to assess potential management concerns for small forest landowners, including mature declining hardwood (particularly red alder) stands, density management, and understocked stands.

3.1   PARCELS AND FOREST ACRES OVERVIEW

The total forest acres in Washington state from the Forestland Database is 19.3 million acres. This is similar to FIA which estimate approximately 22 million acres of forest (USDA Forest Service 2024). The acreage difference is related to how marginal forests are classified by the land cover input datasets (NLCD and GNN) for the Forestland Database and minimum area thresholds for including parcels in the summary calculations (2 parcel acres and ½ forest acres are used in the Forestland Database). From the Forestland Database, SFLO own 2.88 million acres of forestland in Washington state, representing 7% of the forest area in western Washington and 8% in eastern Washington. Table 5 lists the summary of SFLO parcels.

Table 5. Summary of SFLO parcel count and acres in Washington from the Forestland Database.

Half State	Is SFLO	Number of Parcels	Forest Acres	Percent of Forest Acres in State	Percent of Forest Acres in Half State
East	No	34,177	6,471,813	33%	82%
East	Yes	76,489	1,460,060	8%	18%
West	No	77,768	9,910,224	51%	87%
West	Yes	185,248	1,424,966	7%	13%
Total		373,682	19,267,064		

3.2 FOREST CARBON SUMMARY

Statewide, Washington forests store 1.11 billion metric tons of carbon in live above ground and below ground components. This analysis does not consider soil carbon or carbon in snags and downed woody debris. Table 7 compares this estimate to FIA. We used the rFIA package for the R programming language for the analysis (Stanke et al. 2020). Western Washington accounts for 78 percent (867 million metric tons) compared to 21.9 percent in Eastern Washington (246 million metric tons). Ten percent of forest carbon is stored by SFLO (109 million metric tons). On average, SFLO forests store 39.1 metric tons of carbon per acre. A map of the live aboveground and belowground forest carbon prediction raster is provided in Figure 6. Forest carbon is summarized for major owner classes in Table 6.

Total Live Aboveground and Belowground Forest Biomass (metric tons per acre)
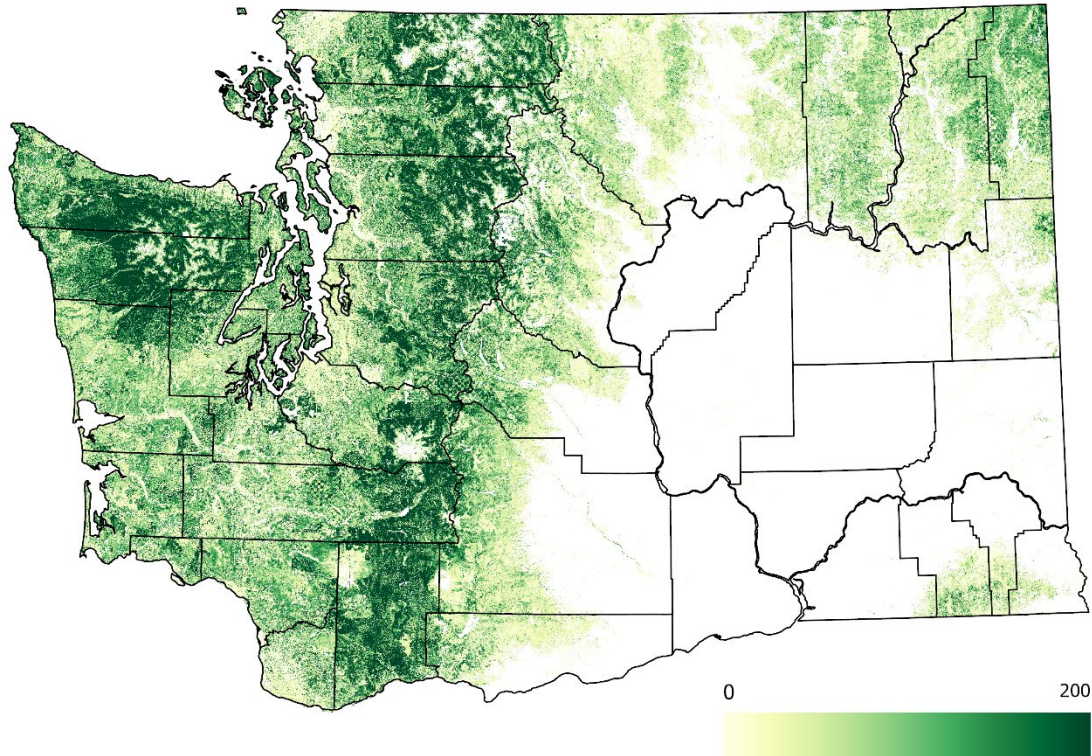
Figure 6. Map of total live aboveground and belowground forest biomass in Washington.

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Table 6. Comparison of live aboveground and belowground forest carbon estimates with FIA.

Source	Total metric tons C (billions)
FIA	1.09 (1.07 – 1.11)
NRSIG	1.11

In western Washington, SFLO forests are estimated to store 76.9 million metric tons of carbon (53.5metric tons per acre). This compares to 45.7 metric tons per acre for private industrial owners and 79.0 metric tons per acre for DNR. In eastern Washington, SFLO forests store 31.9 million metric tons of carbon (21.3 metric tons per acre). All non-Forest Service owner classes store a similar amount of carbon per acre.

For comparison, we produced forest carbon estimates from FIA plots located on SFLO parcels from the Forestland Database. The results agree well on a per acre basis for both eastern and western Washington (Table 7). The estimates are also very close for total carbon in eastern Washington. The forest acres in western Washington were underestimated by about 2.7 million acres from the FIA plots. This resulted in an underestimation in total carbon in western Washington.

Table 7. Summary of live aboveground and belowground carbon for SFLO forests in Washington using prediction rasters and the Forestland Database.

	West			East		
Owner Class	Forest Acres	Metric Tons Per Acre C	Total Metric Tons C	Forest Acres	Metric Tons Per Acre C	Total Metric Tons C
SFLO	1,423,714	53.5	76,911,725	1,460,819	21.3	31,935,417
Private Industrial	3,419,852	45.7	151,678,611	835,933	22.2	17,698,731
Tribal	357,882	47.1	17,931,111	1,068,252	22.1	30,214,059
DNR	1,269,914	79.0	108,110,245	514,803	27.8	16,337,915
Forest Service	3,137,029	107.9	369,048,703	3,701,111	38.2	159,878,816
Summary	11,739,608	73.9	867,318,306	8,036,122	30.7	246,330,750

Table 8. Summary of live aboveground and belowground carbon for SFLO forests using FIA and the Forestland Database.

	West			East		
Owner Class	Forest Acres	Metric Tons Per Acre C	Total Metric Tons C	Forest Acres	Metric Tons Per Acre C	Total Metric Tons C
SFLO	1,150,000	50.59	58,100,000	1,400,000	20.33	28,400,000

3.3   FOREST STRUCTURE SUMMARY

We calculated the average forest attributes for SFLO and other major owner classes for western and eastern Washington. Broad management trends can be identified from these averages. In western

Washington, SFLO forests have lower trees per acre (TPA) with a larger average diameter than industrial forests. DNR forests have higher TPA and larger QMD on average. However, this includes both managed areas and those set aside for habitat requirements. National Forests contain the largest and densest forests on average. These trends are expected given known management regimes. In eastern Washington, SFLO forests have lower density on average compared to other major landowners. The results do not suggest an acute stewardship need (e.g. density management) for SFLO forests.

Table 9. Average forest structure attributes for major owner classes in Washington using prediction rasters and the Forestland Database.

Half State	Owner Class Name	TPA	BAA	QMD	RSDI	BF
West	SFLO	175	130	11.6	0.39	24,616
West	Private Industry	242	124	9.5	0.36	17,898
West	Tribal	252	142	10.1	0.37	19,434
West	State DNR	224	187	12.9	0.47	42,234
West	Forest Service	257	237	14.6	0.54	63,759
East	SFLO	111	64	11.2	0.28	8,188
East	Private Industry	139	71	10.4	0.29	8,725
East	Tribal	125	77	11.6	0.33	10,902
East	State DNR	136	84	11.7	0.32	12,356
East	Forest Service	195	114	11.8	0.39	18,312

Average forest attributes can only suggest broad trends in forest conditions. We next classified SFLO forests to identify the number of parcels and forest acres meeting criteria related to specific management concerns. First, we identify SFLO forests dominated by aging hardwood trees. We filtered all SFLO forests with at least 50 percent hardwood proportion by basal area. We classified these acres into four QMD size classes (Table 9). In western Washington we identified 76,041 acres in the largest size class (QMD > 16 inches) and an additional 242,769 acres in the next largest size class (QMD 12-16 inches). A smaller number of acres was identified in eastern Washington. Figure 7 shows the approximate location of these parcels.

Table 10. Summary of SFLO hardwood dominated (hardwood proportion >= .5) forests by QMD size class using prediction rasters and the Forestland Database.

Half State	QMD Size Class	Number Of Parcels	Forest Acres
West	4 to 8 in	61,577	89,307
West	8 to 12 in	117,183	215,518
West	12 to 16 in	130,280	242,769
West	> 16 in	88,343	76,041
East	4 to 8 in	13,998	36,401
East	8 to 12 in	18,647	86,315
East	12 to 16 in	13,613	26,889
East	> 16 in	6,841	5,627

Next, we attempted to identify SFLO forest acres that could benefit potentially benefit from a thinning treatment. We filtered SFLO forests to those with a relative stand density index greater than .55. This threshold is used to approximate when competition related mortality will occur (Drew and Flewelling 1979). Forests tend to increase in relative density with growth. We classified the forest acres into QMD size classes to prioritize thinning opportunities in smaller and younger size classes. In western Washington, we identified 53,194 acres in the 8-to-12-inch size and 184,849 acres in the 12-to-16-inch size class (Table 10). A map of these parcels is provided in Figure 8

Table 11. Summary of SFLO dense (RSDI > .55) forests by QMD size class using prediction rasters and the Forestland Database.

Half State	QMD Size Class	Number Of Parcels	Forest Acres
West	4 to 8 in	1,713	596
	8 to 12 in	50,135	53,194
	12 to 16 in	123,657	184,849
	> 16 in	123,240	191,552
East	4 to 8 in	595	180
	8 to 12 in	24,304	23,855
	12 to 16 in	47,451	83,083
	> 16 in	36,128	46,925

Finally, we summarized SFLO forests to determine if low stocking was an issue. We filtered to stands with a relative stand density index less than .4. This threshold has been used as the lower limit of maximum stand yield (Drew and Flewelling 1979). We then classified the remaining acres by QMD size class. In western Washington we identified 316,901 acres in the 8-to12 inch size class and 132,864 acres in the 12-to-16-inch size class that might support higher stand density (Table 11). A large number of acres was also identified in eastern Washington. However, forest management in these forests is complex. The acres likely include recent fires, thinnings for fire risk reduction, multi-aged stands, and stands with low maximum stand density indexes. Figure 9 maps these parcels.

Table 12. Summary of SFLO sparse (RSDI < .4) forests by QMD size class using prediction rasters and the Forestland Database.

Half State	QMD Size Class	Number Of Parcels	Forest Acres
West	4 to 8 in	143,970	380,739
	8 to 12 in	169,335	316,901
	12 to 16 in	164,335	132,864
	> 16 in	100,632	31,344
East	4 to 8 in	66,467	290,622
	8 to 12 in	75,733	881,364
	12 to 16 in	74,776	438,355
	> 16 in	42,096	34,187

Figure 7. Map of SFLO parcels with hardwood dominated (hardwood proportion >= .5) forests by QMD size class.

Figure 8. Map of SFLO parcels with dense (RSDI > .55) forests by QMD size class.

Figure 9. Map of SFLO parcels with sparse (RSDI < .4) forests by QMD size class.

4 Developing a Demonstration Tool for a Remote Sensing Based Forest Carbon Program

Figure 10. Screen capture of the Washington Small Forest Landowner Carbon Project Demonstration Tool.

4.1 Overview

To demonstrate how the remote sensing forest inventory could be used for a forest carbon program, we developed a web application based on the VM00045 protocol (Figure 10). We used the shiny package for the R programming language (Chang et al. 2023). The first step is to allow a user to define the boundaries of a project by clicking on a map (with further development, a parcel boundary could be selected, or a shapefile could be uploaded). Aerial imagery and parcel boundaries assist the user to identify the area of interest. The tool crops a set of forest rasters to represent the current forest condition for the project. The attributes selected for western Washington are listed in Table 12.

Table 13. Root mean squared error (RMSE) for models used in the demonstration tool.

Attribute	Project-Scale RMSE
TPA GE 4	76.3
QMD GE 4	3.8
Height of Top 40 TPA	13.2
Total Live Forest Biomass	43.8
Hardwood Percent	7.2
PSME Percent	20.8
TSHE Percent	15.6

Project activities and growth were represented using matched FIA plots simulated with the Forest Vegetation Simulator (FVS). We emphasize that the FVS simulations are necessary for the demonstration tool but not for the VM00045 protocol or a remote sensing-based carbon program. We identified the most similar FIA plot (k = 1) for each raster cell in the project. This differs from the VM00045 protocol which matches the 10 closes neighbors for the baseline using the average forest condition for a project. We felt retaining the variation in forest conditions during simulations was a better representation of the project. Results were then averaged to compare against baseline simulations. The web application reports the average forest attributes for the project to allow a user to compare the remotely sensed inventory against local knowledge (Table 13).

Next, a user selects a treatment for the project. We simulated four active management treatments plus no action for each FIA plot. The treatments include final harvest, a light and heavy thin, and a precommercial thin. All treatments occur in the first time period for a project. The tool summarizes forest carbon and carbon in harvested wood products over 50 years for the matched FIA plots in a project. The selected project parameters are reported by the tool.

Table 14. The demonstration tool reports project parameters and estimated forest attributes.

Project parameters

Parameter	Value
Acres	13.86
Treatment	Heavy thin
Percent of project area treated	80.41
Baseline assumption	Business-as-usual

Forest attributes

Attribute	Modeled value
TPA_GE4	362.46
QMD_GE4	8.93
Ht_Top40	66.60
TAGB	67.96
Hardwood_Percent	9.05
PSME_Percent	93.45
TSHE_Percent	12.87

We closely followed the VM00045 protocol in selecting FIA plots for the baseline scenarios. We matched the 10 most similar FIA plots based on the average forest attributes for a project. We weighted each plot based on its similarity score (the Euclidean distance calculated using scaled attributes). FVS simulations for the matched plots were used to develop the baseline scenarios.

The baseline in VM00045 is intended to represent business-as-usual forest management. FVS simulates growth and treatments but does not determine when treatments occur. To generate baseline scenarios, we first determined an annual probability of harvest for SFLO forests. For each scenario, the tool compares a randomly generated number to this rate for each plot in each time period. If the number is less than the threshold, a final harvest simulation for the plot is selected. Otherwise, the tool assumes no action. We randomly generate 30 baseline scenarios for a project in the tool to calculate mean, minimum, and maximum carbon values.

After generating the baseline scenarios, the tool displays two output charts. The first chart compares the project carbon against the mean baseline scenario (Figure 11). The range of the baseline scenarios is also provided. In the second chart, panels show carbon by component (stem, bark, branch, foliage, root, and harvested wood products) for the project and mean baseline scenario (Figure 12).

Figure 11. An example chart from the demonstration tool showing simulated carbon (forest + harvested wood products) for a project. The project is compared to a set of 30 baseline business-as-usual scenarios generated by the tool.
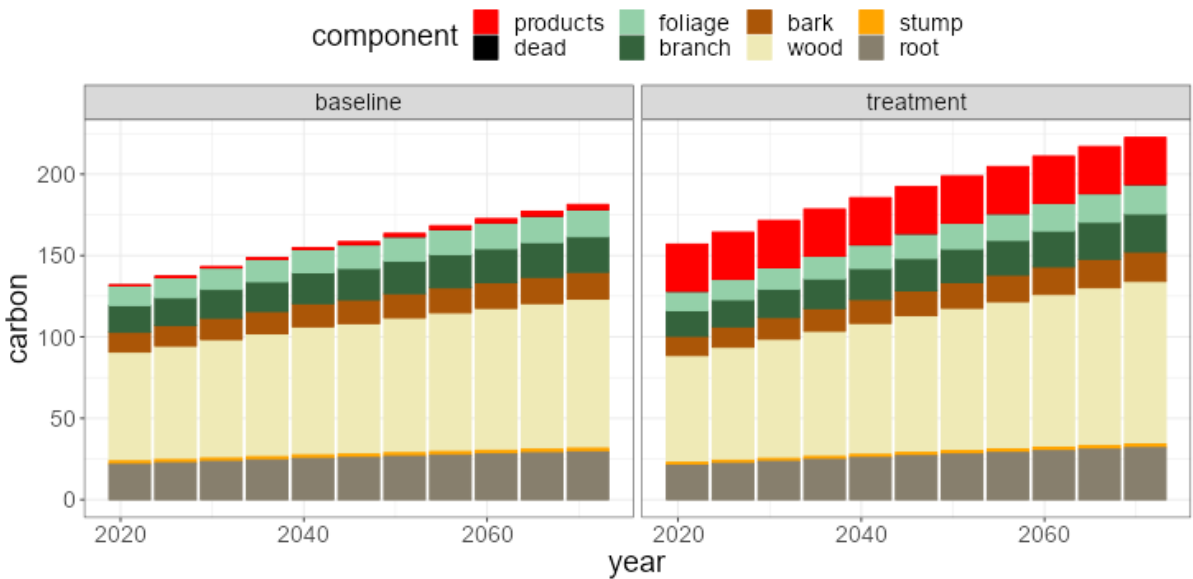
Figure 12. An example chart from the demonstration tool showing carbon by component for a project. The project is compared to the mean value for 30 baseline scenarios.

The tool calculates carbon additionality following VM00045, although we do not translate carbon into carbon dioxide equivalent (CO_2e). Additionality is based on differences in forest carbon growth between scenarios plus carbon stored in harvested wood products. The tool displays a table of additionality over time for a project compared to mean and extreme baseline scenarios. The tool also reports the number of times (out of 30) the project results in positive carbon additionality.

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The tool was developed to evaluate the option to use remote sensing forest inventory for a carbon program, and to allow users to assess the accuracy of the predicted forest attributes against local knowledge. The tool does not report more detailed forest inventory data (such as tree-list predictions) due to confidentiality concerns by the FIA program. FIA is not allowed to share the exact location of FIA plots on privately owned land. Predictions of forest attributes have become accurate enough that FIA plots could be uniquely identified from the combination of predictions and other publicly available datasets. Addressing this issue could allow valuable forest information to be made available for a wide range of management and research purposes.

4.2 CHOICE OF PROJECT AND BASELINE FIA PLOTS

We had the choice of using the same FIA plots for both the project and baseline scenarios, matched either on a raster cell-by-cell basis or using the average forest conditions. This would have minimized the effect of FVS bias in calculating additionality. We felt this was not the best representation of VM00045, in which project field plots are not identical to baseline plots.

4.3 FIA PLOT MATCHING DONOR POOL ANALYSIS

The Verra protocol compares forest growth and management activities for a project against a set of matched FIA plots. A pool of candidate plots is identified that meets certain criteria, including: 1) Plots must be located in the same ecoregion (US Forest Service ecological section) (Cleland et al. 2007); 2) Plots must have completed two measurement cycles; 3) Plots must not have more than one condition (e.g. multiple owner classes or forest types); 4) Plots must have the same stand origin category (natural or artificial regeneration) as the project unit; 5) Plots must be of the same forest type group as the project unit; and 6) Plots must be of the same ownership class (public or private) as the project unit.

Although the criteria are logical for comparing a project against forests of similar type, growth rates, and management intensities, the conditions are overly restrictive for establishing an adequately sized donor pool in Washington state. Table 14 lists the plots and acres for a recent FIA inventory and the number of plots remaining after applying some of the criteria. For SFLO, the most restrictive criterion is owner class, with only 1,668 FIA Plots located on private land. Limiting FIA plots to private owner class that have been remeasured and with only one condition leaves 492 plots.

Table 15. An analysis of FIA plots in Washington remaining after applying criteria used for defining a donor matching pool for a project in VM00045.

Criteria	Number of FIA Plots	Acres
All current forested plots	5908	21,944,950
Private owner class	1668	9,859,306
Remeasured	4027	14,934,075
One Condition	3231	11,628,312

Table 15 illustrates the cumulative impact of the criteria for four major forest types in Washington. For a project in a privately owned planted Douglas-fir (PSME) forest in Western Washington, 144 plots are available in the final donor pool. No more than 16 plots are available in the other three examples. These plots then need to be matched to project-specific conditions. The Verra protocol matches on stand age, site productivity class code, elevation, slope, commercial stocking, quadratic mean diameter, and

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horizontal distance to road. A match quality score is calculated using the standardized difference of means, with a required value 0.25 or less to be deemed valid (Shoch et al. 2022). Given the small number of plots available for major forest types in Washington, it is unlikely (or impossible) to use the approach described in VM00045 in Washington. The Verra protocol was developed with a focus on the eastern United States with little public land and a 5-year remeasurement cycle for FIA. These issues represent challenges to adopting the protocol in the western United States.

Table 16. Examples by half state and forest type group of the cumulative effect of applying the donor matching criteria in VM00045 on FIA plot count for a private planted forest Washington.

Number of FIA Plots Available for a Donor Matching Pool for a Project on a Privately Owned Planted Forest				
	Western Washington		Eastern Washington	
Step	PSME	TSHE	PSME	PIPO
All WA	5,908	5,908	5,908	5,908
One Condition	3,231	3,231	3,231	3,231
Remeasured	2,142	2,142	2,142	2,142
Same Half State	1,022	1,022	1,120	1,120
Same Forest Type Group	482	271	453	201
Same Owner Class	159	44	87	107
Same Stand Origin	144	16	3	7

4.4 GROWTH AND YIELD MODELING

We simulated no action and four active management treatments for each FIA plot using the Forest Vegetation Simulator (FVS). We set site index and maximum stand density index values for each plot based on ecoregion and forest type. Growth and mortality were adjusted using keywords (Table 16). We simulated each plot for 10 growth cycles using a 5-year time step (50 years).

Table 17. Keywords used to calibration growth in the Forest Vegetation Simulator.

FVS Keyword	Multiplier Value	Description
BAIMULT	.8	Reduces basal area growth increment.
MORTMULT	2	Increases background mortality
DEFECT/ MCDEFECT/ BFDEFECT	.1	Reduces volume by increasing the proportion of defect

All treatments were implemented in the first time period. Treatments included a final harvest, two thinnings, and a precommercial thin, with residual stand targets differing for each half of the state. Table 17 lists the prescriptions. Trees were removed from below by DBH until the target residual TPA value was achieved. Some treatments were not simulated where no trees were removed.

Table 18. Treatment definitions for the Forest Vegetation Simulator to simulate growth for the demonstration tool.

	Residual TPA Targets	
Treatment Name	West	East
Final Harvest	5	5
Light Thin	250	200
Heavy Thin	150	100
Precommercial Thin	300	300

4.5   HARVESTED WOOD PRODUCTS

The calculation of carbon additionality for a project is dependent on assumptions made about how long carbon is sequestered in short- and long-lived wood products and in the landfill, emissions from fuel usage during harvest operations and transportation, and leakage. Leakage may be related to change in harvest rates or substitution of alternative building materials in response to the project. The VM00045 protocol accounts for some of these. It assumes emissions from fuel usage is negligible. It does account for activity-shifting leakage. We do not consider fuel emissions or leakage in this project.

VM00045 assumes a portion of log mass remains after 100 years, dependent on species type (hardwood/softwood), product type (sawlog/pulp), and ecoregion (eastern/western Washington). Factors for Washington softwood products include .511 for western sawlogs, .119 for western pulp, and .415 for both eastern product types. Our tool currently assumes a factor of .4, although simulated tree records have been bucked into log small end diameter size classes using taper equations (Kozak, Munro, and Smith 1969). A more advanced harvested wood products model differentiating wood products from log sizes could be applied in the future. Research by the Consortium for Research on Renewable Industrial Material (CORRIM) indicates more specific factors should be applied to improve estimates of carbon stored in harvested wood products, dependent on log sizes (Oneil and Puttmann 2024).

4.6   SMALL FOREST LANDOWNER HARVEST RATES

To create baseline scenarios, we analyzed SFLO forest cover loss over 20 years. We intersected SFLO parcels from the Forestland Database with fire burn severity rasters (Eidenshink et al. 2007), an insect and disease aerial survey layer (Washington State Department of Natural Resources 2024), and forest cover loss raster (Hansen et al. 2013). We assumed forest cover loss not associated with fire or pathogens must be from harvesting activity. A brief analysis suggested the forest cover loss raster may not detect thinnings. For this analysis, we assumed all SFLO harvests were final harvests and that thinning acres are underestimated.

To determine the total SFLO forest acres we used the 2019 Forestland Database. We summed the forested upland acres by county. We know this overestimates SFLO acres in previous years because it does not account for conversion to other land uses. Based on the frequency of harvest activity and the size of the SFLO land base, we calculated the annual probability of harvest by county. The web application currently uses the weighted average probability by half state, though county level estimates could be used in the future. The harvest probability values were .00977 and .00749 in western and eastern Washington, respectively. The implied harvest ages of 102 years (west) and 134 years (east) seem reasonable for SFLO.

4.7 IMPROVING FOREST CARBON ACCOUNTING

The VM00045 protocol does not account for some aspects of forest management that may impact the carbon benefits from a project. VM00045 assumes emissions from harvest operations and transportation are de minimis. Our web application (and underlying datasets) provides a framework to remove the need for this assumption. A site-specific analysis allows emissions associated with a logging operation to be estimated. This include fuel usage from move-in and move-out operations, logging system type (ground or cable), and transportation. Site-specific economic costs also determine whether a project is economically feasible and therefore whether harvested logs become wood products. An example of this type of site-specific analysis is the Biomass Calculator, which is built on previous versions of the Forestland Database and predicted forest inventory ([Biomass Calculator (washington.edu)](washington.edu)).

Forest condition is also important. Tree size impacts fuel usage for felling (it is more efficient to cut fewer larger trees). Log size determines the number of trips required to deliver logs to a mill. The types of wood products and the amount of carbon stored over time also depends on log size. Mill efficiency is also affected by log size.

The web application demonstrates the element of randomness associated with choosing 10 matching FIA plots to establish a business-as-usual baseline. Other voluntary carbon markets (American Carbon Registry) are investigating geospatial baselines. This approach requires accuracy in remote sensing forest inventories to be sufficient and transparent to be defensible. Previous forest inventory models (without DAP- or Sentinel-derived predictor variables) have not been accurate enough to use for a project-scale analysis. Emerging forest inventories from private companies are unlikely to be transparent enough in model accuracy or methodology. The forest models developed for this project may satisfy both criteria. Unlike VM00045, the geospatial approach represents a census of harvest activities and disturbance events that occur within a region of interest, removing the element of chance in scoring a project.

If properly resourced, a program based on NAIP imagery would also be updated more frequently than a program based on FIA plots. In the western United States, FIA plots are remeasured on a 10-year cycle ($1/10^{th}$ of FIA plots are remeasured every year). This could result in a significant lag in events registering in baseline plots. In contrast, NAIP is acquired on a 2-year interval.

A geospatial baseline approach also has the potential to account for forest conversion to development. Forest retention should be the highest priority of any forest carbon program. Bizarrely, VM00045 resets the baseline when a matched FIA plot is developed by reweighting the remaining nine plots. A geospatial approach would census forest conversion. Further, the most recent update of the Forestland Database included an analysis of conversion risk in Washington between 2007 and 2019 (Rabotyagov et al. 2021). Not surprisingly, forest parcels near major cities were at greatest risk of conversion. The datasets described in this project could be utilized to develop a forest carbon program that prioritizes forest retention.

4.8 UNCERTAINTY

VM00045 accounts for sampling error in the estimation of the carbon change for both project plots and matched FIA plots. An uncertainty factor is calculated from the variances and applied to reduce the carbon credits for a project. Our models have error associated with model predictions instead of

sampling error. It is necessary to determine how to incorporate this type of uncertainty if remotely sensed inventory is used in place of field plots.

5 CONCLUSIONS

The forest species and structure rasters produced for this project are the highest resolution publicly available datasets of forest conditions in Washington state. Paired with the Forestland Database, these rasters provide an unprecedented foundation for forest resource assessment. The summaries of SFLO parcel in this report provide brief case studies. The NAIP acquisition schedule would allow new forest rasters to be made on a 2-year cycle. A regularly updated set of forest rasters and Forestland Database would provide a strong foundation for a state forest carbon program and support other research.

The demonstration tool provides the ability to sample potential projects. While the tool uses some simplified methods, a survey of test cases indicate most projects result in very little carbon additionality, translating into little financial benefit for a small forest landowner. A payment program focusing exclusively on carbon additionality is dubious, especially when future value is discounted.

Forest management regimes with known benefits, such as thinning in eastern Washington to reduce fire risk and increase resiliency, may not result in carbon stored in harvested wood products. Forest health treatments may not increase carbon directly but build resilience and survivability of forest stands when a wildfire occurs, ultimately a better carbon outcome. The treatment should be incentivized before the fire occurs. Similarly, precommercial thinnings on the Olympic Peninsula result in more windfirm future stands among other ecological benefits. VM00045 acknowledges precommercial thinning is outside the scope of the protocol (though it may be included in other existing or future Verra protocols).

6 RECOMMENDATIONS

Datasets derived from digital aerial photogrammetry of NAIP images will become a foundational input to research and analysis of Washington forests. It has a higher spatial resolution than satellite imagery and the high temporal resolution (2 years between image acquisition) necessary to monitor forest disturbances and track growth. Remotely sensed forest inventory is approaching accuracies that allow for site specific assessments rather than regional trends. Model errors are larger than we would like (TPA +- 76; QMD +- 4 inches; Biomass +- 50 tons) but opportunities exist for continued improvement. Research is necessary to determine how best to utilize DAP in general and specifically related to a forest carbon program. We recommend funding for:

1. The production of statewide forest composition and structure raster datasets from future DAP acquisitions. Continued funding is necessary to produce these models as NAIP imagery is acquired at a 2-year interval.
2. The production of an updated Forestland Database of parcels, ideally at a frequency that matches NAIP acquisitions (2-year interval). The Forestland Database is the sole source of small forest landowner information available and the definitive source of forest conversion data in Washington state. Pairing frequently updated, DAP-based forest composition and structure estimates with concurrent parcel data would greatly enhance the States ability to quantify

forest change related to conversion, management activities, disturbance events, and changing productivity. Each of these have significant impacts on forest carbon sequestration and storage.

3. A study on the stability of DAP-based predictions over time. This study demonstrated improved accuracy in predictions for validation stands (3 to 150 acres) compared to plots (.1 to .25 acre). It is necessary to determine at what spatial and temporal scales we can have confidence to detect real change in sequential predictions.

4. A study on leveraging repeated DAP measurements to improve stability in predictions. Error is present in DAP height estimates due to issues such as light condition at time of image acquisition and pixel off nadir angle. A sequence of DAP measurements can be used to smooth predictions and identify and correct errors, resulting in more stable estimates of forest growth and change.

5. A study evaluating model performance and data needs by modeling region and forest type. Overall model accuracies obscure data or modeling issues specific to a particular forest. Validation stands underrepresent a number of conditions in both western and eastern Washington: 1) only eight validation stands exist in eastern Washington; 2) a number of species are not present in any validation stand; 3) validation stands underrepresent high elevation and complex old growth stands; 4) both validation stands and field plots may underrepresent riparian forests. A study is needed to determine data gaps to improve future modeling efforts and our ability to validate models.

6. A study addressing modeling issues in low density eastern Washington forests. Two issues were identified related to sparse forests. First, DAP processing tends to "smear" canopy surfaces where forest gaps are present, resulting in low estimates of canopy height and elimination of openings. Second, grass and shrubs visible in openings are not distinguished from trees when summarizing Sentinel-2 and CCDC. A potential solution is to use image segmentation techniques to first classify trees and non-trees. A study is needed to determine the effectiveness of this or other strategies to improve models in low density forests.

7. A study on the use of deep learning models to predict forest composition and structure. Neural nets consistently show improved accuracies over other techniques for a wide range of problems. This topic has the potential for an extended line of research including the use of recurrent convolutional neural networks to leverage time series for satellite and DAP datasets to improve predictions. This study should fund a PhD student or post-doctorate position with expertise in artificial intelligence. Challenges include the need to overcome FIA use limitations due to confidentiality requirements.

8. A study on methodologies to satisfy FIA confidentiality requirements while allowing an attributed plot dataset to be used in a cloud computing environment such as Google Earth Engine. Current FIA use limitations add significant expense to research projects and limit the quality of the results. Methods have been outlined to overcome this challenge. A study should be funded to determine if these methods satisfy the FIA program, allowing modeling products to be made public. It would also allow the Plot Database to be available for researchers.

9. A study on the advantages and drawbacks of using a geospatial baseline instead of a dynamic plot baseline for quantifying carbon additionality for a project. The protocol developed by Verra used the 10 most similar FIA plots to determine a business-as-usual alternative against which to compare project activities. This study identified issues with this approach including a scarcity of plots from the private owner class and an element of chance in the baseline events for any

particular project due to the small number of plots used. DAP-based carbon estimates represent a census of growth, management activities, and disturbance events against which a project could be compared. The implications of this alternative approach and how best to ensure its adoption in carbon protocols should be investigated.

10. Updated resource assessments (timber/biomass supply study, forest conversion risk study, etc.) for Washington state.
11. A study to investigate unintended consequences of carbon markets specifically, is needed. Perceived benefits associated with no-action or delayed action management regimes may be offset by a slew of unintended consequences including increased emissions associated with future harvests due to sparse mill infrastructure, a lack of workforce due to decreased harvest activity, increased fire risk associated with a changing climate, and loss of the forest land base due to economic pressures from decreased timber value from all of the above.
12. Ensuring access to frequent direct forest measurements such as DAP should be a priority for the legislature on behalf of Washington's natural resource management agencies and academic researchers. The National Agriculture Imagery Program Digital Aerial Photogrammetrically (NAIP DAP) derived point clouds have proven valuable in improving remotely sensed structure models. The State should invest in NAIP DAP acquisition from the US Governments vendor. Coordinating this purchase with the US Forest Service may be beneficial. Without access to the DAP data, analyses will be no better than those done by commercial vendors that cater to the corporate voluntary carbon markets which have been the subject of multiple newsworthy investigations into their "real, permanent, quantifiable, verifiable, and enforceable" offsets.

6.1 PROGRAMMATIC APPROACHES TO CONTINUED ASSESSMENTS

Programmatic funding for ongoing statewide assessment and monitoring of forest conditions and land use change is needed. Currently funded efforts at the Washington State Department of Natural Resources are limited to state lands and statewide assessments are sporadically funded, inconsistent, and inadequate for cap-and-trade carbon markets. Envisioned are a few different models for how this could be implemented.

1. Enable the UW Precision Forestry Cooperative to be a Cost Center, much like CINTRAFOR (http://www.cintrafor.org/), creating a pathway for programmatic, legislatively dedicated funding for advancing this work.
2. Establish a Public Benefit Corporation to advance this work in a transparent and open way.
3. Establish a new independent UW or collaborative higher-ed/agency organization to advance this work.

6.2 CONCERNS AND CHALLENGES

- How to establish programmatic funding and ensure timely updates?
- VM00045 accounts for uncertainty in sampling estimates by discounting the carbon emission reductions by a factor calculated from plot variance. Our approach has prediction uncertainty associated with modeling. The methods to account for this type of uncertainty need to be developed.
- Limited FIA plots and infrequent remeasurements may necessitate a longer reassessment period. Alternatively, a geospatial approach utilizing the Washington State Forestland Database

and the forest structure and species models could be used to establish a baseline scenario and monitor change.

- Exact FIA plot locations and landowner information are protected by Federal law under the Food Security Act of 1985, Public Law 99-198 Stat. 1657, December 23, 1985, Confidentiality of Information, 7 U.S.C. 2276 (note clause d(10), as amended through Public Law 106-113, Nov. 29, 1999. This confidentiality requirement extends to products developed from actual FIA plot locations such that plot coordinates cannot be "reverse engineered" from the derivative products. With the advances in remotely sensed forest structure and species models developed as part of this project and others, methods for sharing derivative products that maintain high-fidelity predictions while simultaneously protecting landowner confidentiality need to be developed.
- Existing "improved forest management" carbon protocols enforce long-term contracts in an effort to achieve "permanent" offsets. Nothing about forests are permanent. Many landowners, especially small family forests, may be reluctant to enter into contracts with multi-generational timelines. Conceptually, financial pressures exacerbated by carbon markets that encourage longer-term forest rotations could lead to a decrease in timber value and an increase in forestland conversion to non-forest uses for those owners disinterested in such long-term contracts. Creating a protocol that rewards carbon smart forest stewardship with shorter term contracts utilizing frequent independent remotely-sensed forest assessments may increase participation in carbon markets and help preserve the forest land-base.

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Appendix 2:

Carbon Flows and Pool of Harvested Wood Products – Washington State

Draft Final Report

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Background

Historically, a preferred environmental product was one that was made from renewable or recycled resources. Today, carbon footprints dictate some purchasing preferences across sectors. Wood-based products that have low embodied carbon (emissions from production measured in carbon dioxide equivalents (CO_2e)) and energy are sought out though other functional aspects such as longevity, durability, recyclability, and disposal options other than landfilling are also desired.

Producing all materials, renewable and non-renewable, has environmental impacts. Life cycle assessment (LCA) has become increasingly important as a tool used by all industries to inform product and process designs that minimize energy consumption and carbon release. For wood products, international standards and the North American Wood Product "Product Category Rule" (PCR) provide guidance on reporting the LCA of wood products that meet international verification standards. These reports are always on a product production basis (e.g. functional unit of a cubic meter, or metric ton, or square meter of material). LCA typically does not assess social aspects of sustainability and rarely does a product LCA consider impacts back to the landscape level, or in our instance reporting the impacts of producing a specific wood product back to the forest from which the wood was harvested. That level of granularity has not previously been possible beyond specific cases with high impact (and good budgets) like the data used for the wood that went into the award-winning Portland International Airport (PDX) renovation.

Given the goal and scope of this project, advances were made towards increasing the granularity of LCA estimates that could be incorporated into the spatial database effort developed concurrent with this project as part of the larger Washington State Small Forest Landowner Carbon Workgroup (hereafter CWG) authorized under SB 5126 (2021).

As part of the CWG, CORRIM was asked to determine carbon implications from harvesting wood products (HWP) by small forestland landowners (SFLO) in Washington State. The goal was to link the wood product (e.g., lumber, plywood, pulp) to harvested volumes directly from SFLO using a life cycle assessment (LCA) methodology. Understanding the wood and carbon flows would contribute to the assessment of carbon impacts of HWP that could be incorporated into the broader assessment of forest land management activities. The LCA results were used to develop the cradle to gate embodied carbon for each product produced from SFLO. Linking the embodied carbon to carbon stocks and storage in products provides an overall understanding of SFLO's contribution to Washington State's forest sector carbon sequestration.

The Timber Product Output (TPO)[1], though dated (2018), can provide a general understanding of harvested species and end use allocation (Figure 1). These allocations can be further supported by the American Wood Councils online LCA reporting surveys that show the industries that are producing wood products in the State of Washington. Due to significant differences in forest productivity, recovery potential, carbon footprint, and milling infrastructure, this analysis separates the LCA into the westside and eastside of Washington (Figure 2).

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[1] https://www.fs.usda.gov/research/products/dataandtools/tools/timber-products-output-tpo-interactive-reporting-tool
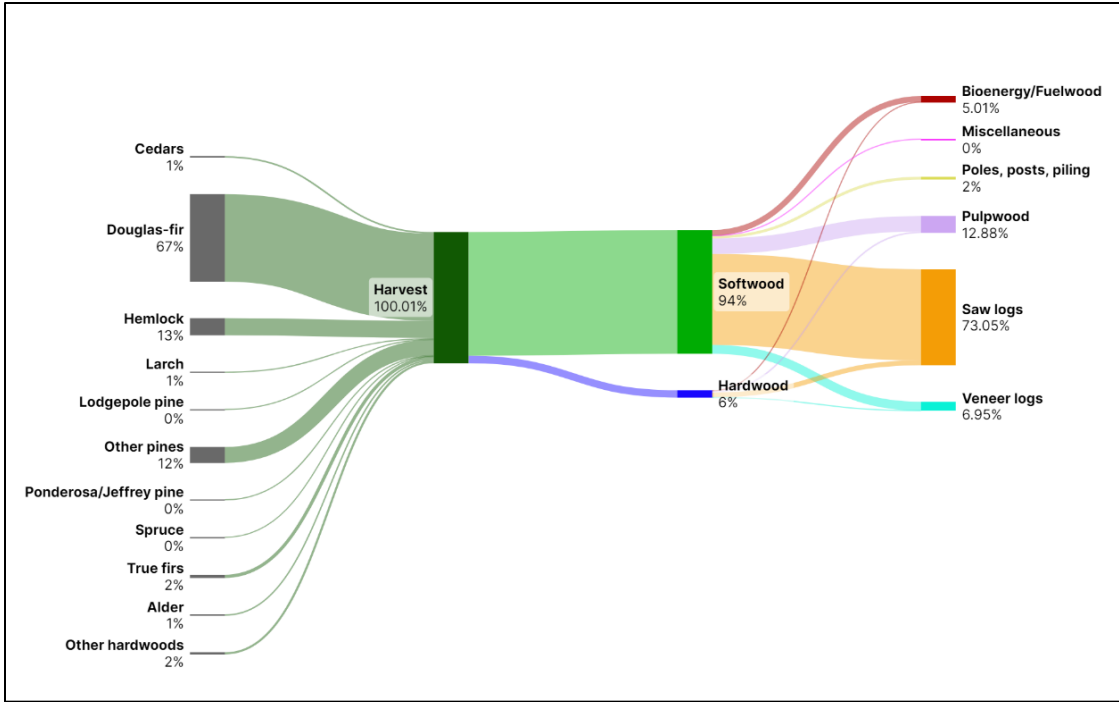
Figure 1 Allocation of wood products by forest species representing total harvest for Washington State (TPO 2018)
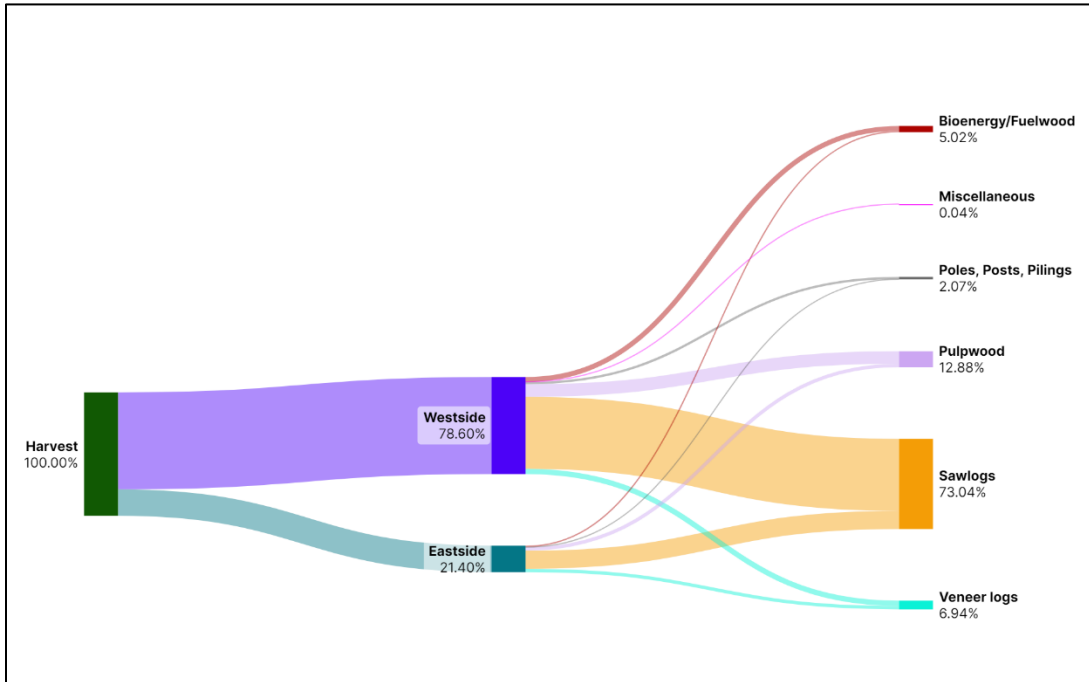
Figure 2 Allocation of wood products by west and eastside for Washington State (TPO 2018)

1 What is Life Cycle Assessment

Life-cycle assessment (LCA) has evolved as an internationally accepted method to analyze complex impacts and outputs of a product or process and the corresponding effects they might have on the environment. LCA is an objective process to evaluate a product's life cycle by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and materials uses and releases on the environment; and to evaluate and implement opportunities to effect environmental improvements. LCA studies can evaluate full product life cycles, often referred to as "cradle-to-grave", or incorporate only a portion of the products life cycle, referred to as "cradle-to-gate", or "gate-to-gate". This study can be categorized as a cradle-to-gate LCA as it includes forestry operations through production of the product ready for shipment.

As defined by the International Organization for Standardization (ISO 2006a-b)[2], LCA is a multiphase process consisting of a 1) Goal and Scope Definition, 2) Life Cycle Inventory (LCI), 3) Life Cycle Impact Assessment (LCIA), and 4) Interpretation (Figure 3). These steps are interconnected, and their outcomes are based on goals and purposes of a study.

Figure 3 Steps involved in a life cycle assessment.
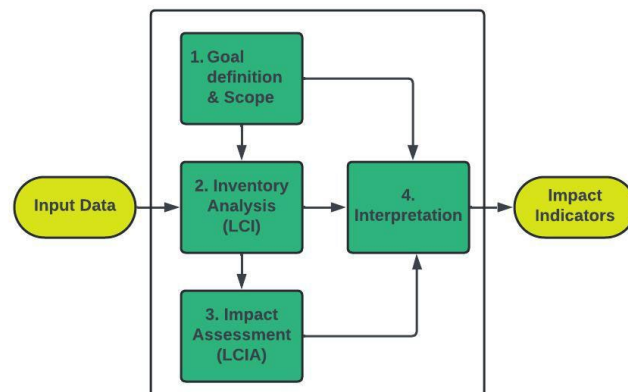
An LCA begins with a project goal, scope, functional unit, system boundaries, any assumptions and study limitations, method of allocation, and the impact categories that will be used.

The key component is the LCI which is an objective, data-based process of quantifying energy and raw material requirements, air emissions, waterborne effluents, solid waste, and other environmental releases occurring within the system boundaries. It is this information that provides a quantitative basis for comparing wood products, their manufacturing processes and, alternatives to their production and use.

The LCIA process characterizes and assesses the effects of environmental releases identified in the LCI into impact categories such as global warming, acidification, eutrophication, ozone depletion, and smog.

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[2] International Organization for Standardization ISO. 2006a. Environmental management—Life-cycle assessment—Requirements and guidelines. ISO 14044:2006/Amd1:2017/Amd:2:2020. International Organization for Standardization, Geneva, Switzerland. 46 pp/8 pp/12 pp/.
International Organization for Standardization ISO. 2006b. Environmental management—Life-cycle assessment—Principles and framework. ISO 14040. International Organization for Standardization, Geneva, Switzerland. 14040:2006/Amd1:2020. 20 pp/8 pp.

The life cycle interpretation is a phase of LCA in which the findings of either the LCI or the LCIA, or both, are evaluated in relation to the defined goal and scope to reach conclusions and recommendations. This final step in an LCA involves an investigation of significant environmental aspects (e.g., energy use, greenhouse gases), their contributions to the indicators under consideration, and which unit processes (e.g. wood drying, transport) in the system are generating the emissions. For example, if the results of a LCIA indicate a particularly high value for the global warming potential indicator, the analyst could refer to the inventory to determine which environmental flows are contributing to the high value, and which unit processes contribute to those outputs. This is also used as a form of *quality control*, and the results can be used to refine the scope definition to focus on the more important unit processes. This step also supports arriving at more certain conclusions and supportable recommendations.

2 Methods

2.1 System Boundary

Information modules included in the LCA are shown in Table 1 and Figure 4. This LCA includes modules A1-A3 for cradle-to-gate analysis. Additional declared Modules include End of Life (EoL) stages (C2 – C4) to complete a cradle-to-grave module inclusions (ISO 21090 5.2.2)[3]. Due to data gaps, the impact of deconstruction and waste processing (Module C1 and C3) are considered null for this LCA (Sahoo et al. 2021).

Both human activity and capital equipment were excluded from the system boundary. Human activity involved in the manufacturing of any wood product no doubt has a burden on the environment. However, the data collection required to properly quantify human involvement is particularly complicated and allocating such flows to the production of materials as opposed to other societal activities was not feasible for a study of this nature. Typically, human activity is only considered within the system boundary when value-added judgements or substituting capital for labour decisions are within the study scope. These types of decisions are outside the current goal and scope of this study.

Table 1 LCA system boundary modules (ISO 21930). MND – Module Not Declared (not part of this LCA)

PRODUCTION STAGE			CONSTRUCTION STAGE		USE STAGE							END-OF-LIFE STAGE				OPTIONAL BENEFITS
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Extraction and up-stream production	Transport to factory	Manufacturing	Transport to site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Building Operational Energy Use During Product Use	Building Operational Water Use During Product Use	Deconstruction	Transport	Waste	Disposal	Reuse, Recycle, & Recovery benefits

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[3] International Organization for Standardization ISO. 2017. Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services. International Organization for Standardization. Second edition (ISO 21930:2017-07) 80pp.

X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND

(a)

(b)
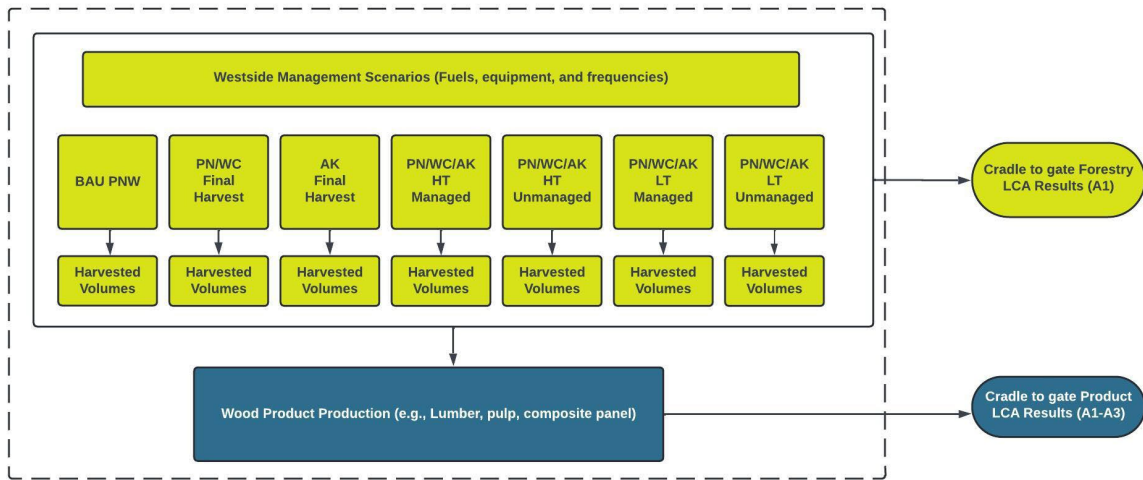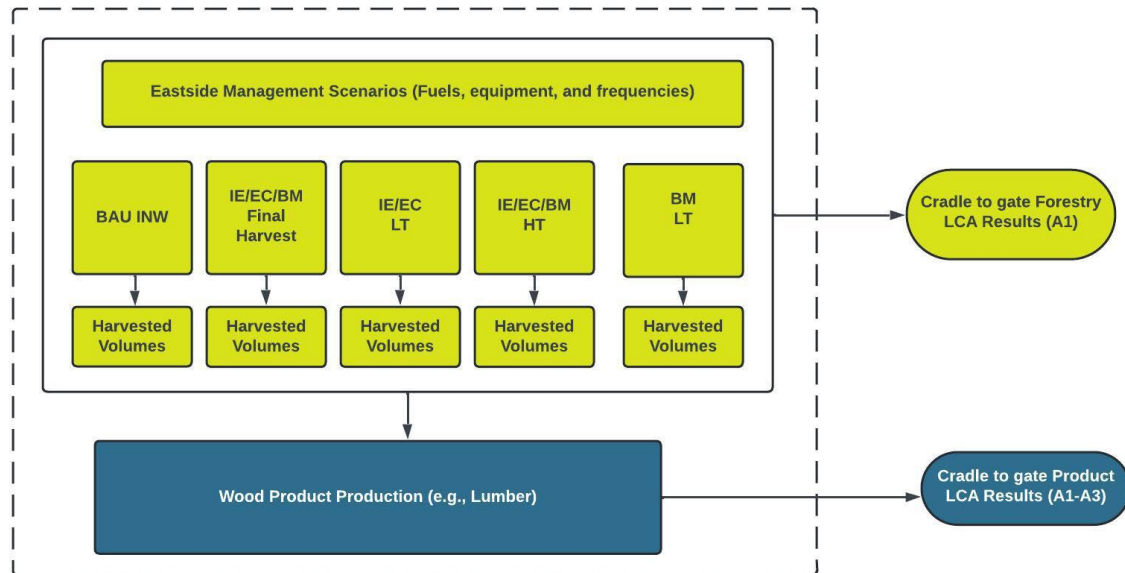
Figure 4 Cradle to gate system flow for all wood products and management scenarios for (a) westside and (b) eastside

For forestry operations, the system boundary is characterized by a mix of the components shown in Figure 4 consistent with the silvicultural system inputs and treatment scenarios for each forest type and management scenario. System boundaries for HWP are shown in Figure 5.
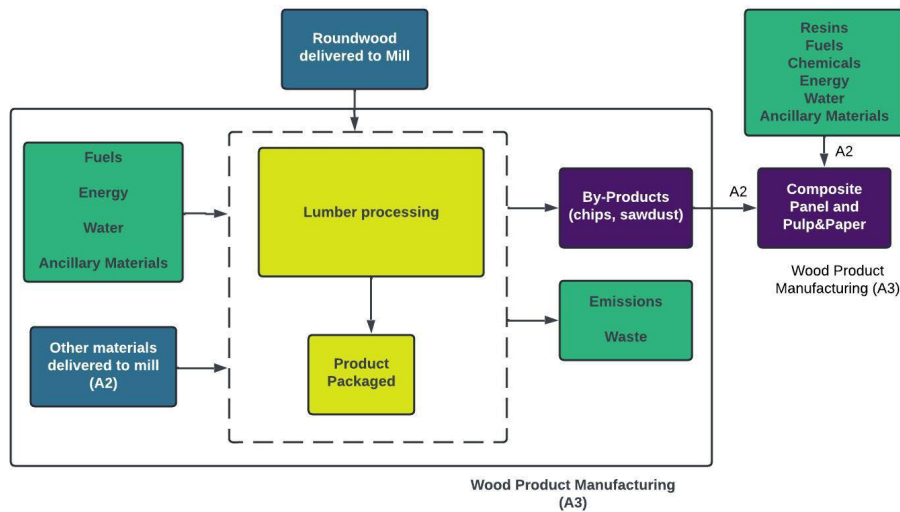
Figure 5 Wood products system boundary including by-product end uses

Specific data used are described in the following sections for Forest Resources Operations and Harvested Wood Products. All secondary data for chemicals, transportation, energy, fuels, and pulp & paper utilized available literature and available LCI processes as part of Datasmart 2023 (LTS 2023)[4], Ecoinvent (v3.8) (Wernet et al. 2016)[5], and the USLCI dataset. All LCA modeling was performed with SimaPro software v. 9.5 (Pre 2023)[6].

2.2 Forest Resources

Full carbon accounting that includes harvested wood products (HWP) requires estimates of the harvest volume and its allocation to a range of products, each with different recovery rates and uses. For region wide estimates weighted average values representing the most common practices are needed. For the scope of this project, site specific data were needed to link back to the statewide database developed by NRSIG. The Forest Inventory and Analysis (FIA) plots in Washington State were aggregated by owner group by NRSIG. Individual plot data proved too unwieldy for forest resource LCA generation therefore data values were generated for each owner type, major forest type, region, and sub-region. Harvest simulations were conducted for each plot based on a series of logical estimation procedures that evaluate diameter, yield, piece size, and stocking. These harvest treatments, including a light thin, heavy thin and final harvest were implemented and the resulting log volumes were estimated based on regionally relevant log scaling rules. Treatment prescriptions employed are found in Table 2.

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[4] LTS. 2023 Datasmart LCI Package http://ltsexperts.com/services/software/datasmart-life-cycleinventory/

[5] Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., & Weidema, B. (2016) The Ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, 21, 1218–1230.

[6] Pré Consultants, B.V. 2023. SimaPro 9.5.0 Life-Cycle Assessment Software Package. Plotter 12, 3821 BB Amersfoort, The Netherlands. Http://www.pre.nl/.

Table 2: Silvicultural Prescriptions for Statewide Treatment and Yield Assessment.

Treatment Name	Residual TPA Targets	
	West	East
Final Harvest	5	5
Light Thin	250	200
Heavy Thin	150	100
Precommercial Thin	300	300

Yield data were disaggregated by scaling diameter (small end of the log merchandized to either 32' (westside Scribner log scaling rules) or 16' (eastside Scribner log scaling rules) to facilitate the assessment of harvest and milling life cycle assessments (LCA). The LCA data, specifically the carbon foot-printing component of the LCA, was provided for future integration into the demonstration tool for the remote sensing-based forest carbon program. Significant progress was made to link the HWP and forest carbon components in this project, but additional work is needed to increase granularity of the LCA carbon estimates based on site specific stand parameters.

Appendix 2, Table 18 through Table 23 provide the scaling diameter distributions by region, sub-region (FVS variant), treatment type (Prescription (Rx)), and major forest type for FIA plots that exist on small forest landowner properties.   Graphically the scaling diameter distributions for small forest landowner plots can be compared to the regional distribution for all owners by comparing Figure 6 to Figure 7 for westside forests, and Figure 8 to Figure 9 for eastside forests. While the general trends are similar across all ownerships, the lower stocking and smaller diameter distributions found on SFLO lands is skewed towards smaller log sizes in nearly all cases. Volume harvested from SFLO properties is also substantially lower than the average across all owners with only minor exceptions. This finding suggests that improved forest management pathways that a) improve stocking and b) manage competition could provide viable carbon improvements, both in the forest and in the HWP carbon pools. Additional comparisons for hardwood and redcedar forests are shown in Appendix 2.
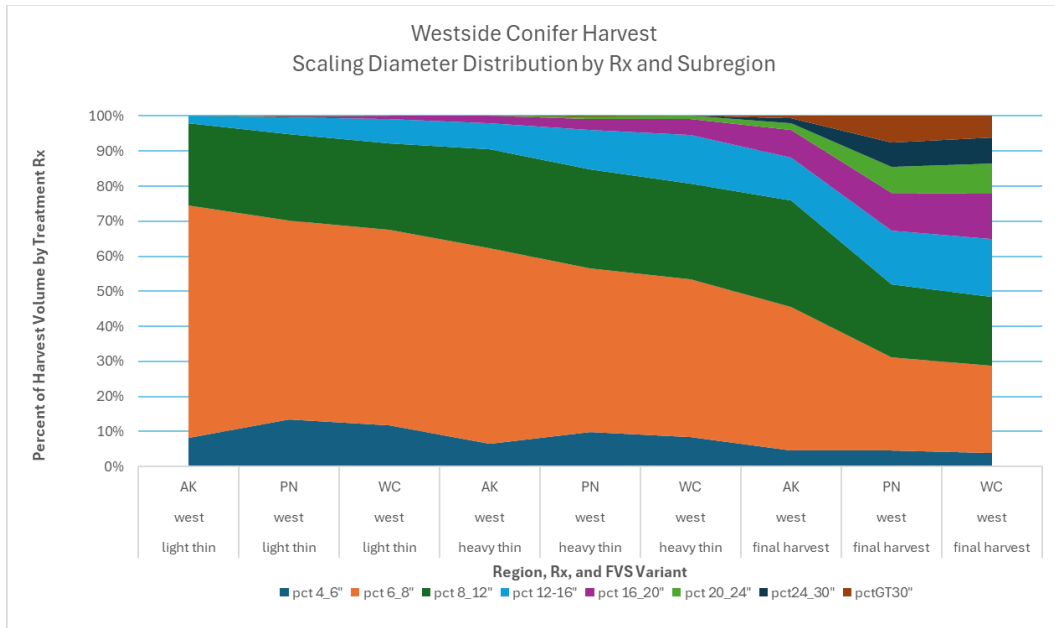
Figure 6: Westside Scaling Diameter by Prescription, Subregion, and Treatment – all owners
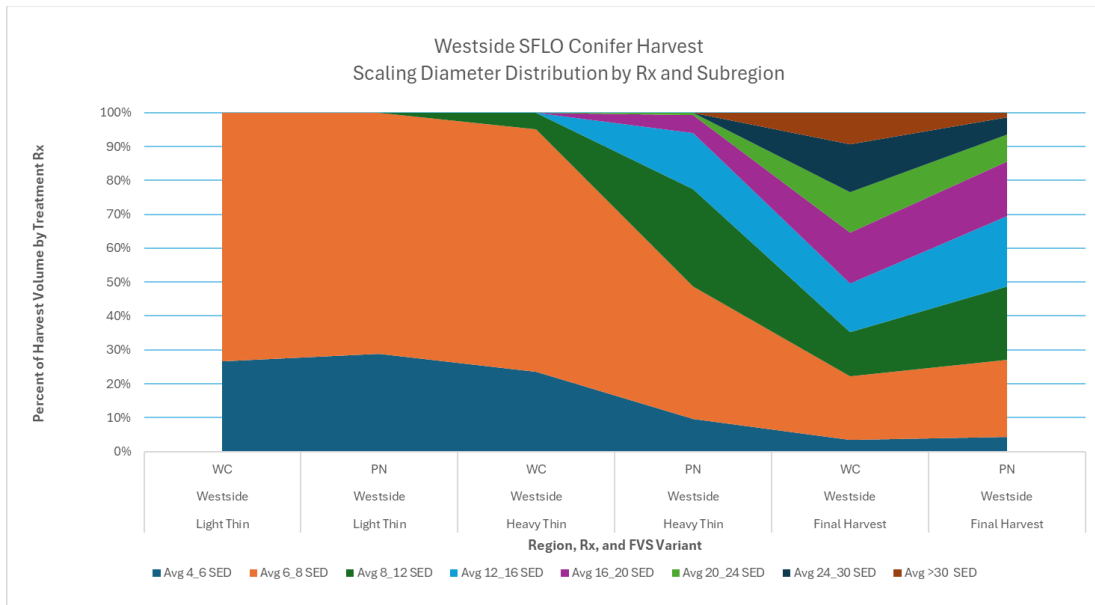
Figure 7: Westside Scaling Diameter by Prescription, Subregion, and Treatment for Conifer Dominated Stands – SFLO
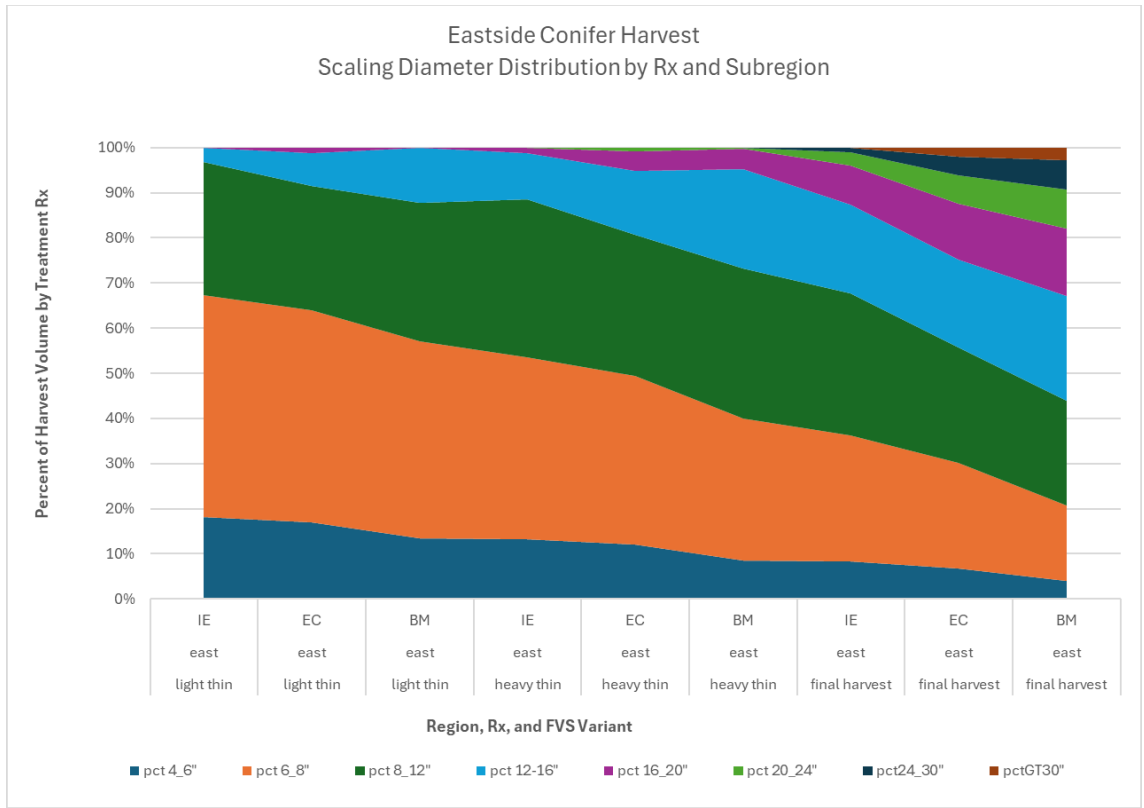
Figure 8: Eastside Scaling Diameter by Prescription, Subregion, and Treatment – all owners
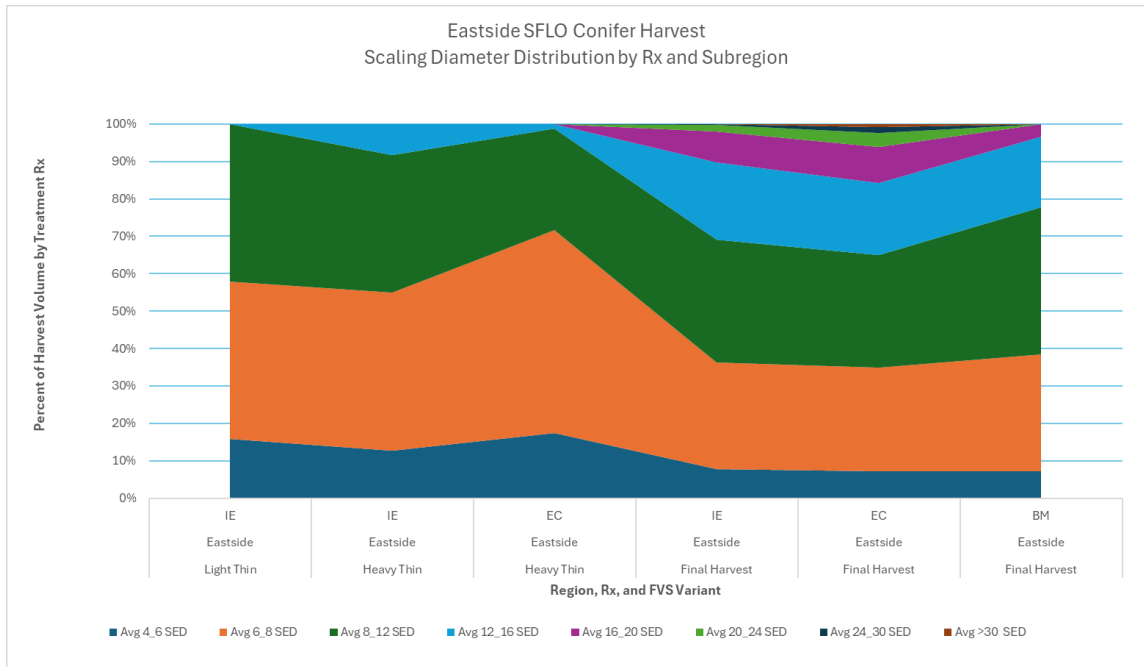
Figure 9: Eastside Scaling Diameter by Prescription, Subregion, and Treatment for Conifer Dominated Stands – SFLO

Scaling diameter distributions coupled with yield were used to create harvesting equipment and logging productivity profiles representative of each region and prescription (light and heavy thin plus final harvest). These profiles were used to produce a range of harvesting LCA that were used as upstream data in the HWP for the most common products produced from these forests. This forestry allocation method is consistent with national and international standards for LCA. Details on these findings are provided in section 3.1

Forest management was not included in the forest resource LCA alternatives for this iteration of the carbon foot-printing tool. The rationale for this exclusion is driven by the allocation processes used in LCA. In short, without a known volume per acre, per acre data inputs cannot be correctly allocated within the LCA. Based on our historical analysis this exclusion is likely to add approximately 5-8% to the forestry carbon footprint depending on the volume removed, with higher per acre volume removals resulting in lower overall footprints per cubic meter of wood.   Method development and database programming to account for site specific forestry operations allocations (i.e. dependent on the stand boundaries chosen) were outside the scope of the work envisioned for this project, but we have provided specific examples as 'proof of concept' for future integration.

In addition to the statewide harvesting LCA data inputs for the database tool, we also conducted a case study that explores the LCA impacts of management. This excellent dataset provides a rare examination of the trade-offs between low, moderate, and high intensity management. It has contributed significantly to the recommendations on 'improved forest management' for carbon market and carbon incentive programs as well as pointing the way for what is needed to incorporate 'longer rotations' as a credible, defensible market strategy.

2.2.1 A Case Study on Improved Forest Management

Carbon foot-printing developed from a Tale of Three stands was used to explore the range of carbon consequences from improved forest management in our westside forests. This long-term retrospective management experiment was fully documented by WFFA members, Bryon and Donna Loucks, over a 35-year period. We gratefully acknowledge their willingness to share detailed data on planting, thinning, density management and harvest. These data were used to compile and generate the data shown in Table 3.

The 3 stands started out identical: planted with 600 Douglas-fir per acre and thinned at age 11 to 300 trees per acre. Stand 1 was left for 30 years and then harvested. Stand 2 had a commercial thin and then a final harvest at 43 years and stand 3 had 2 commercial thins and then a final harvest at year 45. The difference in log size is substantial, though the yield doesn't vary by much. Note that pulp volume (*) was converted to BF at 8.75 tons/MBF by the landowner. This conversion is carried through the analysis of tons, carbon, and carbon footprint.

Table 3: A Tale of Three Stands silviculture, harvesting, and yield comparisons

Treatment Regime	Stand 1 - Low intensity	Stand 2 -Moderate intensity	Stand 3 -High intensity
Age at harvest	41	43	45
	Per acre values		
Pre-commercial thin - age 11	300	300	300
Stocking at final harvest	230	153	100
# commercial entries	1	2	3
Commercial Thin #1	0	4,500*	4,500*
Commercial Thin #2	0		4,273*
Gross Board Feet (BF)	27,972	27,629	29,935
Net BF Final harvest	25,808	26,485	27,927
Total volume removed (merch + non-merch)	27,972	32,129	38,708
Green metric tons removed	168	253	219
Metric tons of carbon removed	51	77	67
Metric tons of carbon per year in product	1.25	1.79	1.48
Log allocation across all stand entries			
#2 sawlog (>12" scaling diameter) export log	0.0%	41.0%	78.3%
9-11.9" export log.	53.3%	31.0%	
#3 and #4 sawlog (5-6" scaling diameter)	33.6%	21.0%	10.7%
pulp	9.4%	7.0%	11.0%
hardwood	3.7%		

Stand 1 had stopped growing and was experiencing significant mortality and loss of live crown. Silvicultural treatment alternatives for such a stand are limited as thinning is unlikely to create a release in a meaningful timeframe given the lack of live crown, and the instability of the remaining trees substantially increases their risk of windthrow while those crowns develop. Thus, the window of opportunity for improved forest management on the stand was largely closed. Under these conditions a harvest and replant scenario is likely to create the largest carbon benefit.

Stand 2 appears to be a sweet spot, both in terms of harvest value and its carbon sequestration per year potential. It generates family income on a 40-45 year time frame (every 2nd generation), but can be modified for longer rotations if the value and carbon benefit support that alternative.

The landowners acknowledged that Stand 3 was still growing really well when it was harvested at 45 years. The stand could have been held another 10-15 years without much expected loss, though there

was concern that individual trees would become too large to attain the high values received from the final harvest at age 45 because oversize logs are worth less, and sometimes a lot less, than logs with large end diameters less than 28". The landowner, who also had significant forestry expertise, expected that if they had been able to leave Stand 3 for another 10-15 years it would have continued to accumulate volume and thus carbon, perhaps reaching 50,000 BF/acre by age 60.

We used those estimates to conduct a scenario analysis on the yield and carbon consequences of managing Stand 3 as it had been managed by extending the rotation to year 60. The comparisons are shown in Table 4, for all parameters but log allocation as we do not have enough detail to speculate on log sort distributions for such a stand. While the metric tons of carbon removed is 55% higher for the extrapolation of stand volume by extending the rotation 15 years, the carbon removed per year is only 17% higher and still does not equal the carbon removed/year by Stand 2 at 43 years. This interplay between density, growth, stand dynamics, soil productivity, (and probably a good deal of luck) means that there can be no one size fits all criteria or recommendation for 'improved forest management' or 'extended rotations'.

Table 4: Experienced and Extrapolated (*) harvesting and yield comparisons for extended rotation stands under managed conditions.

Treatment Regime	Stand 3 -High intensity	Stand 3 – Extended Rotation Pathway*
Age at harvest	45	60
	Per acre values	
Pre-commercial thin - age 11	300	300
Stocking at final harvest	100	85
# commercial entries	3	3
Commercial Thin #1	4,500	4,500
Commercial Thin #2	4,273	4,273
Gross Board Feet (BF)	29,935	50,000
Net BF Final harvest	27,927	46,646
Total volume removed (merch + non-merch)	38,708	58,773
Green metric tons removed	219	341
Metric tons of carbon removed	67	104
Metric tons of carbon per year in product	1.48	1.73

This case study shows that each stand is unique and should be assessed from the perspective of the potential range of options available. Building on the database tools that NRSIG has developed should help make transparent the landowner choices for reasonable silvicultural pathways and the range of carbon consequences that can be expected under these pathways. Ideally these details can be automated so that either forestry navigators or experienced landowners can use the tool for planning and proposal purposes. Ultimately, improvements in granularity and estimation procedures will be needed for the tool to be accepted as part of the carbon assessment process for verifying carbon standards organizations.

2.3 Harvested Wood Products

For the harvested wood products manufacturing, CORRIM has collected regional wood products production data for over 20 years, and this data served as the base data for the LCAs. Thus, the collection of primary production data (LCI input data) from wood product manufacturers in Washington was not needed. Each product used CORRIM LCI data and reporting with modifications to electricity grids and roundwood inputs (Forest Resources) and mill allocations based on log diameter. The pulpwood model for the production of pulp for paper was developed using LCI databases as part the Datasmart (2023) and Ecoinvent (v3.9) datasets within the SimaPro software.

Based on data availability, we assumed the main harvest volumes were sawlogs. This is further supported by the TPO product allocation for sawlogs which was 75 percent for the westside and 69 percent for the eastside (Figure 6). Furthermore, this LCA assumes all softwood roundwood for sawlogs and is also supported by the TPO data which represents 93 percent and 98 percent of the volume harvested for the westside and eastside, respectively.
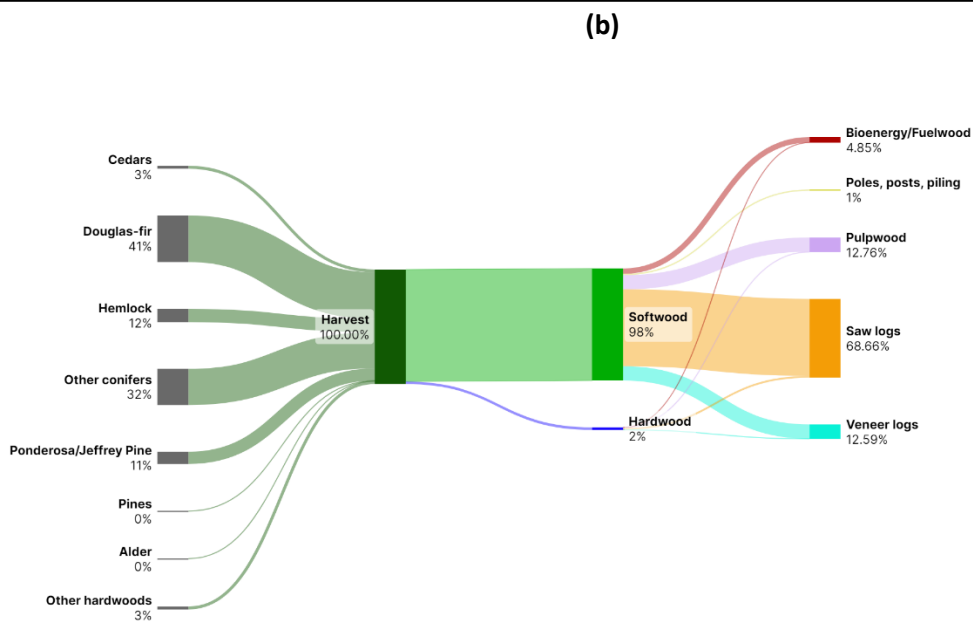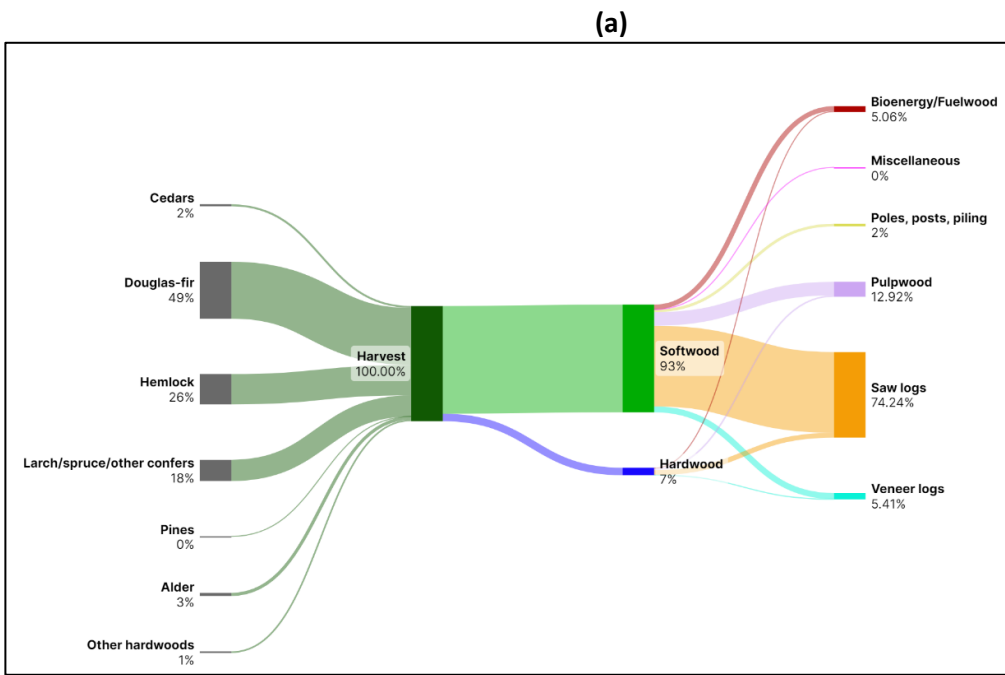
Figure 10 Allocation of wood products by forest species representing westside (a) and eastside (b) harvest for Washington State (TPO 2018)

2.3.1 Softwood Lumber Manufacturing

Softwood lumber manufacturing used two different LCA models. The first is the regional Pacific Coast LCA which represents western Washington and Oregon, and northern California (Puettmann 2024)[7]. This LCA model was used for all final harvest and BAU PNW (Table 2). For all thinning scenarios, a representative Washington "sawmill" was developed using a roundwood input of less than 8-inches small end diameter. See Appendix 1 for a Case Study.

Table 5 Westside management scenarios and associated softwood lumber model use

Management Scenario	LCA Softwood Lumber Model	Source
PN/WC Final Harvest	Regional LCA model	Puettmann 2024
AK Final Harvest	Regional LCA model	Puettmann 2024
PN/WC/AK HT Manag.	Representative sawmill <8" log input	
PN/WC/AK HT Unmanaged	Representative sawmill <8" log input	
PN/WC/AK LT Manag.	Representative sawmill <8" log input	
PN/WC/AK HT Unmanaged	Representative sawmill <8" log input	
BAU PNW	Regional LCA model	Puettmann 2024

Lumber manufacturing was divided into three-unit processes: log yard/sawing, drying, and planing. The wood boiler represents a fourth process that provides steam for drying. Figure 7 shows the relationship between the processes and the woody inputs to and from each process. The primary product from softwood sawmills is construction grade lumber. Other products (by-products) are also made when logs, which are round in cross section, are processed into lumber, which is rectangular in cross section. These by-products could include chips for pulp and sawdust and shavings for panels, paper, or fuel. Logs arrive at the mill with much of the tree's bark intact. The bark is removed and used for fuel or sold for landscaping. Another product of the mill is hog fuel, which can be bark or a mix of bark and wood depending on how individual mills classify it. Hog fuel goes to a boiler or can be sold (Figure 8).
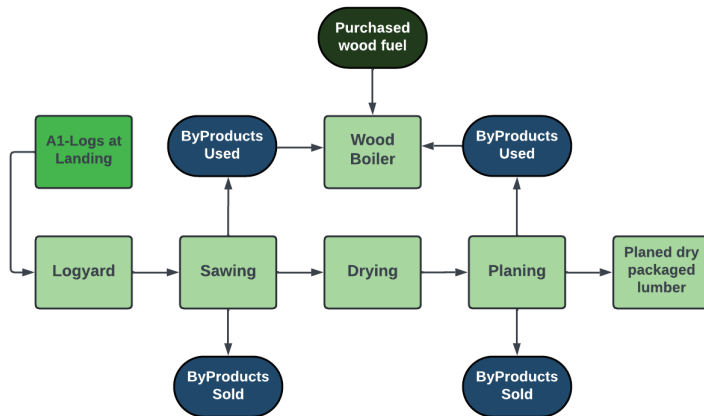
Figure 11 Sawmill unit processes from roundwood to planed dry lumber from logs

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[7] Puettmann, M. 2024. Life cycle assessment of softwood lumber production-Pacific Coast. CORRIM Draft Report. 47pp

CORRIMs extensive LCA reports have a plethora of data that support Figure 8 and the use of the byproducts. Based on 2012 surveys, the softwood lumber industry generated 17,125 thousand metric tons of wood residues, while the plywood industry generated an additional 2,470 thousand metric tons. Durable wood products such as wood composite panels (WCP) use approximately 9,705 thousand metric tons of these residues annually (Table 3). The

Figure 12 Wood biomass flow in an average PNW softwood lumber production facility. Data is based on survey of manufacturers in the PNW

softwood lumber industry in PNW generated nearly 100 percent of their heat energy from these residues for drying wood (www.corrim.org). The plywood industry used 98 percent of their residues to dry veneer or supply steam to presses.

Table 6 Byproduct use in various composite panel products, survey data. Byproducts originate from both hardwood and softwood lumber industries.

Product	Demand mt/annual production
Fiberboard	202,085
Hardboard	668,837
Particleboard	4,962,033
MDF	3,872,950
Total used	**9,705,905**

Two products were chosen for downstream end use of the byproducts from softwood lumber facilities: composite panels and pulp & paper. For these LCA models we assumed that 100 percent of the input feedstock to these manufacturing process is from the by-products of softwood lumber manufacturers in the form of chips and sawdust. This assumption is supported for composite panels from recent LCAs where 84 percent of the input feedstock for particleboard production and 81 percent for MDF was from mill residues. The products used in this LCA for utilization of Washington sawmill residues are medium density fiberboard and uncoated freesheet paper. The uncoated freesheet paper model reported approximately 66 percent of the input feedstock from mill residues.

2.3.2 Substitution Impacts

Every product and use have a different carbon impact. Substitution analysis reports on the emissions of wood products versus an equivalent alternative building material. It is based on three components:

- How much carbon does the product store?
- What is the product embodied carbon?
- What is the displacement between two functional equivalent products?

Wood is 50 percent carbon by dry weight. That carbon remains in the product for its lifetime. Most comparable product alternatives do not store carbon, though efforts are underway to develop technical methods for concrete to store carbon.

Wood growth, harvest, and manufacturing generates less carbon emissions than most other non-biobased materials. Differences arise because the non-biobased materials usually emit substantially more fossil fuel emissions during production. These differences for functionally equivalent materials (e.g., steel stud vs wood stud) translate into climate benefits from using wood products as measured in carbon equivalents. They are reported as a substitution value or substitution pool.

When substitution benefits or avoided emissions are of interest, the carbon storage of the product can have a significant impact. The difference between the embodied carbon and the carbon storage gives the net carbon value (Eq 5.1).

Equation 5.1:

$$\textbf{\textit{Embodied carbon }(GWP_{FOSSIL}) - Carbon\ stored\ in\ product = Net\ carbon\ storage\ (-)or\ emission\ (+)}$$

Equation 5.2 calculates the carbon (as CO2) displaced or avoided emission because a wood product was used over an alternative material. Another way of stating this is carbon not emitted because a wood product was used over an alternative

Equation 5.2:

$$\textit{Net Carbon stored in product of the wood product} - \textit{net emission of steel} = \textit{Avoided emission}$$

The displacement calculation incorporates the value in the net carbon storage of a wood product (difference in emission and storage) and the net carbon emission or storage of the alternative (Eq. 5.3).

Equation 5.3:

$$\mathbf{-15.90\ \textit{kg CO2eq.} - 17.97\ \textit{kg CO2eq} = -33.87} \qquad \textbf{\textit{Carbon displacement}}$$

These concepts are illustrated in Figure 13, using a functional unit of square meter of wall or floor made with wood inputs versus non-wood inputs. Here the signs (+/-) are reversed so that avoided emissions show up as a benefit (net wood becomes positive, net steel is negative, the difference is a positive benefit). This is in contrast to the IPCC and US GHG reporting which shows atmospheric reductions as negative values.

Figure 1: Net Carbon Stored & Carbon Emissions Displaced (kg CO_2/m^2 of Wall or Floor)
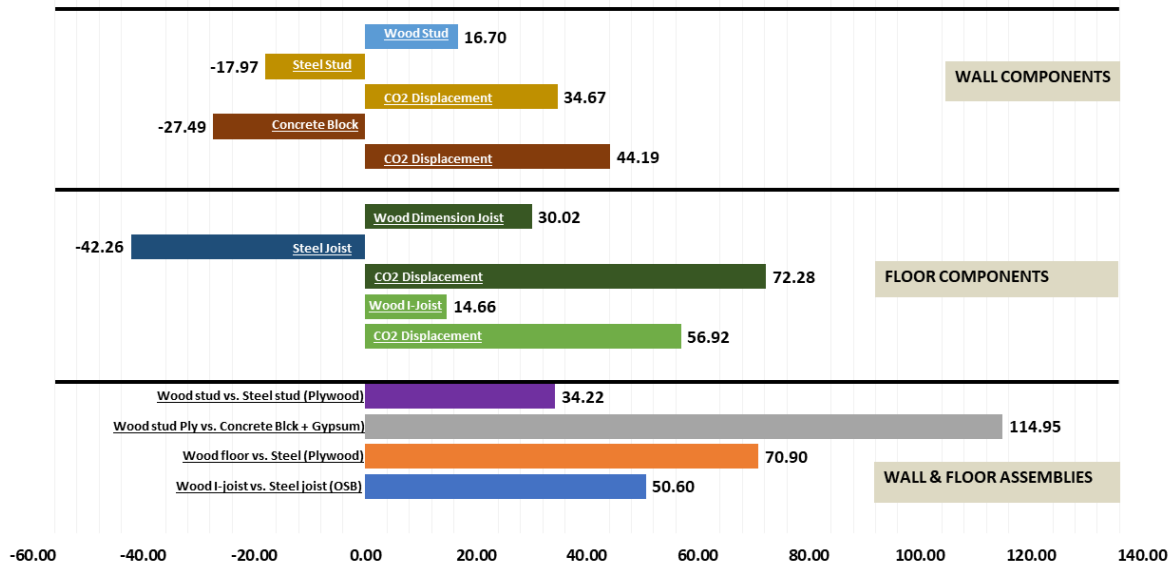
Figure 13 Example of showing how substitution benefits of wood can be presented. Source: www.corrim.org

3 LCA Results

3.1 A1- Forest Resources

3.1.1 Regional and Sub-regional Harvesting LCA Results

LCA data representative of SFLO harvest intensities by region (westside/eastside), sub-region (using the proxy of FVS variant), and treatment type (light thin, heavy thin, and final harvest) were generated based on model inputs from the NRSIG generated scaling diameter distributions, harvesting efficiencies complied from prior research (Oneil and Puettmann, 2017), (Oneil 2021), and unpublished survey data gathered for this project. As noted in the Forest Resources section (2.2), a decision was made to exclude forest management in the forest resource LCA alternatives for this iteration of the carbon foot-printing tool. This means that the INW BAU and Average PNW harvest values are expected to be higher than harvest only scenarios as they include management activities. That is not always the case as Table 7 shows higher values for some of the thinning scenarios. These high values reflect the carbon costs of low intensity management that employs light thinning for stand maintenance.

Table 7: Forest Harvesting GWP and its relationship to A1 for Westside Rx and Sub-regions

treatment unit	Forest Harvesting GWP*	A1	Ratio[1/]
PN/WC final harvest	6.31	7.88	1.25
AK final harvest	7.06	8.83	1.25
PN/WC/AK heavy thin, managed stands	7.04	8.36	1.19
PN/WC/AK heavy thin, unmanaged stands	8.80	10.45	1.19

PN/WC/AK light thin managed stands	11.82	14.03	1.19
PN/WC/AK light thin unmanaged stands	17.73	21.04	1.19
average PNW harvest* (includes management)	8.88	15.47	1.74

1/ allocated log input for wood production, includes self-generated fuel from the log input

Table 8: Forest Harvesting GWP and its relationship to A1 for Eastside Rx and Sub-regions

treatment unit	Forest Harvesting GWP*	A1	Ratio[1/]
IE/EC light thin	12.08	15.34	1.27
BM light thin	11.01	13.98	1.27
IE/EC/BM heavy thin	10.36	13.16	1.27
IE/EC/BM final harvest	9.71	14.76	1.52
BAU INW (includes management)*	13.10	20.17	1.54

1/ allocated log input for wood production, includes self-generated fuel from the log input

3.1.2 A Tale of Three Stands Case Study Results

The log allocation from a Tale of Three Stands case study (Figure 14), combined with specific input data on forestry operations, thinning operations, and harvesting efficiency were used to generate a forest resources LCA comparison using SimaPro 9.5.2 (Pre 2024) (Figure 15).

Figure 15 shows that stands 2 and 3 have a 12 to 13% lower carbon footprint per m3 than stand 1 despite having 1 and 2 more stand entries respectively. These results are largely a factor of the high volume per acre on these managed stands concentrated on fewer, larger trees and the subsequent harvest efficiencies that occur under those conditions. In this case study the thinning impact is not dominating the final outcome because it represents on 13% and 12% of total stand volume in stands 2 and 3 respectively.
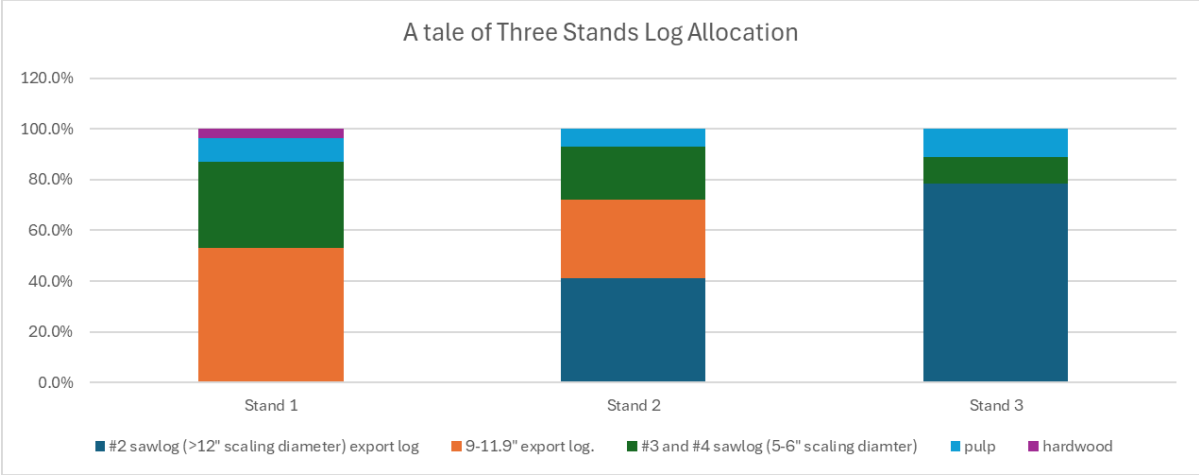
Figure 14: Log allocation by diameter distribution of A Tale of Three Stands
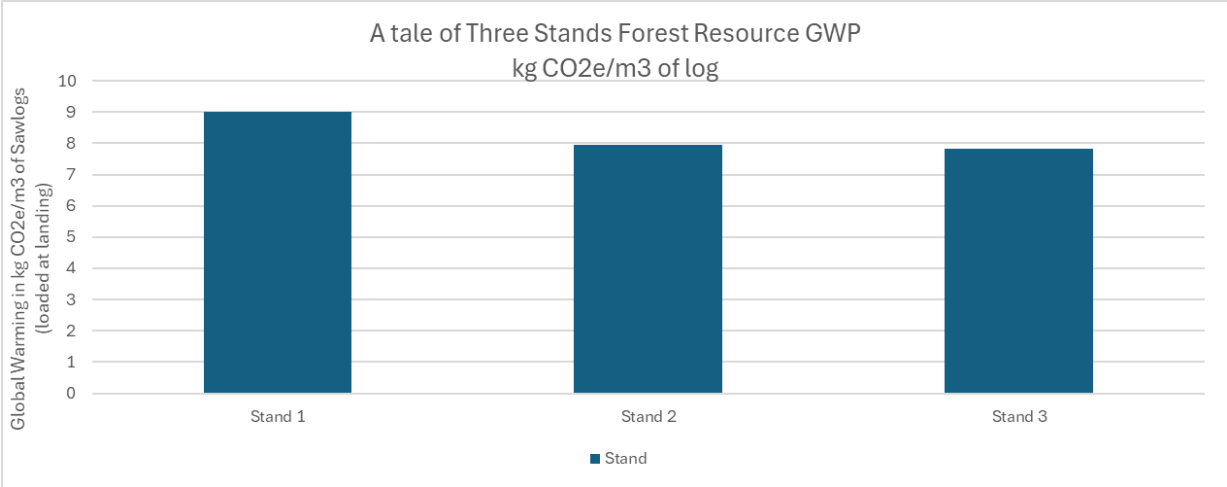
Figure 15: Carbon Footprint/m3 for Planting, Thinning and Harvesting for A Tale of Three Stands.

3.2 A1-A3 Harvested Wood Products

3.2.1 Softwood Sawlog to Lumber

The fraction of log cubic volume recovered as lumber is called the cubic recovery ratio (CRR). It is an accurate and consistent measure of the conversion efficiency used in scanners in sawmills to measure the log and lumber dimensions. As log diameter increases, the fraction of the log recovered as rough green lumber increases, and the fraction of by-products such as chips decreases while sawdust decreases. In a Case Study Using LCA to predict impacts based on log diameter (Appendix 1), representative softwood producers for western Washington, the CRR ranged from 0.46 to 0.68. The CRR for Pacific Coast sawmills was 0.497 m^3_{lumber}/m^3_{log} (Puettmann 2024). Table 4 shows the difference in log

allocation depending on the sawmill model used, log input, and CRR for both west- and eastside sawmill models.

Table 9 Log volume used, allocation to final product, and cubic recovery ratio for the LCA softwood sawmills models

Sawmill LCA Model	Log allocation	Input Log m3/m3 of product produced (unallocated)	Cubic Recovery Ratio
Westside <8" log	56.2%	1.74	0.56
Westside BAU	52.6%	1.90	0.53
Eastside <8" log	34.4%	2.91	0.34
Eastside BAU	48.2%	2.32	0.48

All carbon dioxide flows (kg CO_2eq) presented in the following figures are allocated to a cubic meter of softwood lumber and do not include any by-products leaving the system boundary. The carbon accounting reported uses the embodied carbon and the carbon stored in the wood product. Carbon storage is based on the carbon content of the wood product converted to CO_2e. Table 5 shows the cradle top gate embodied carbon by life cycle module for softwood lumber manufacturing. The A2 and A3 modules are constant within each LCA softwood lumber model that was used. As mentioned above, all final harvest scenarios used the Pacific Coast softwood lumber LCA (Puettmann 2024), while the thinning scenarios used a Washington representative sawmill processing logs under 8-inches (Table 2). The A1 module differs due to equipment use differences and frequencies as described above. Figure 10 shows the relative differences between each life cycle module (A1-A3) for both west – eastside management scenarios. Differences between the two regions for A2 and A3 modules are mostly driven by log allocation. Both softwood models derived most of the onsite energy from self-generated fuels, while the smaller log diameter model had lower lumber allocations (Table 5). The eastside sawmill's primary product, lumber, would have less of the mill operations (energy consumption), than the allocation of mill inputs to westside sawmills. Surprisingly, the smaller diameter sawmill model for the westside had a higher allocation than the BAU Pacific Coast regional sawmill model.

Table 10 Embodied carbon, kg CO2e/m3, for softwood lumber production for each management scenario and life cycle module.

Management Scenario	A1 - Forestry	A2 - Transport	A3 - Manufacturing	TOTAL
Westside	Embodied Carbon kg CO2e per m3 of product			
PN/WC Final Harvest	7.88	8.69	49.65	66.22
AK Final Harvest	8.83	8.69	49.65	67.16
PN/WC/AK HT Managed	8.36	9.72	80.32	98.41
PN/WC/AK HT Unmanaged	10.45	9.72	80.32	100.50
PN/WC/AK LT Managed	14.03	9.72	80.32	104.08
PN/WC/AK LT Unmanaged	21.04	9.72	80.32	111.09
BAU PNW Final Harvest	15.47	8.69	49.65	73.81
Eastside	Embodied Carbon kg CO2e per m3 of product			
IE/EC LT	15.34	6.53	19.02	40.88

BM LT	13.98	6.53	19.02	39.52
IE/EC/BM HT	13.16	6.53	19.02	38.70
IE/EC/BM Final Harvest	14.76	11.09	41.95	67.80
BAU INW Final Harvest	20.17	11.09	41.95	73.21
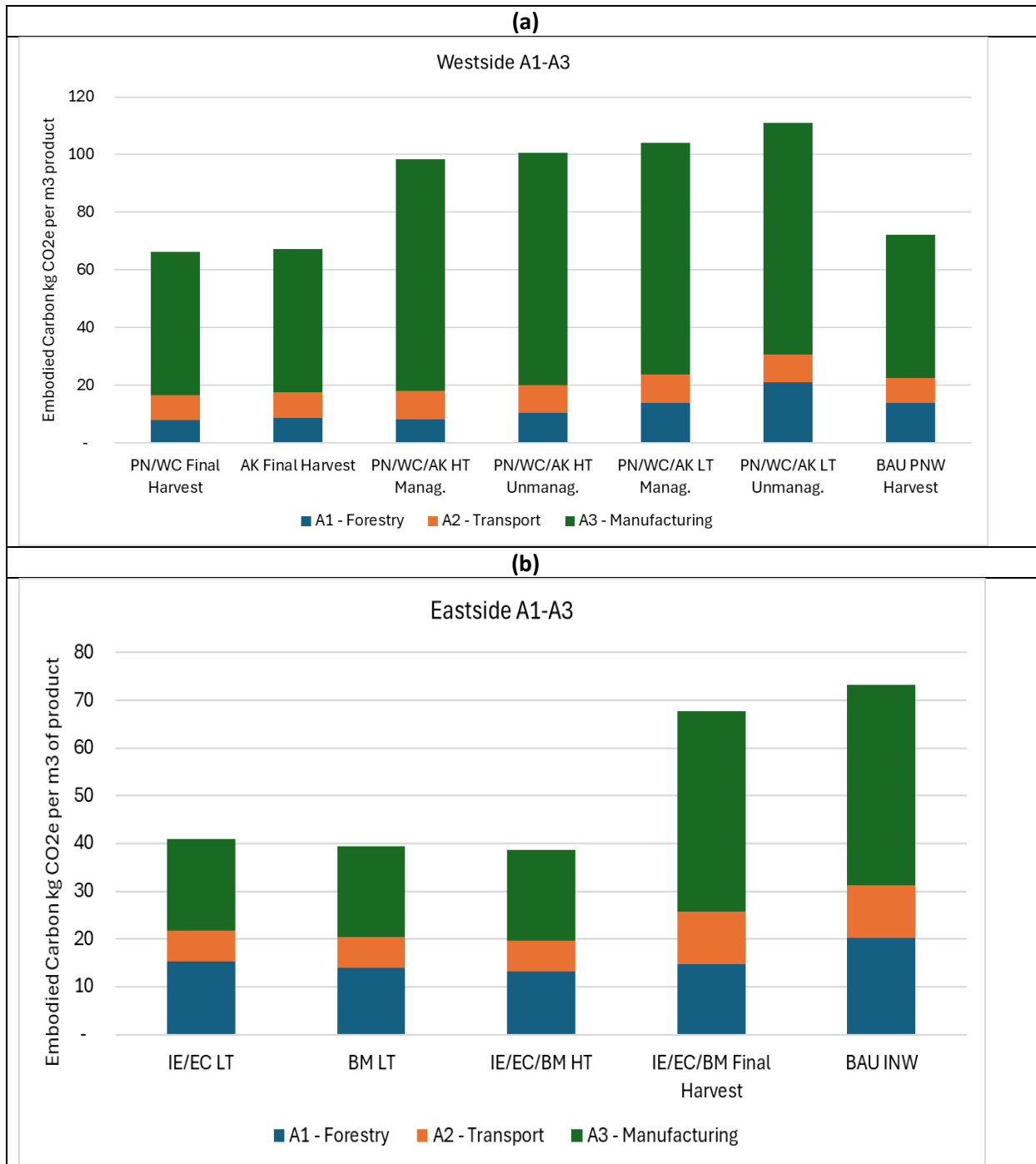
Figure 16 A1-A3 embodied carbon by life cycle stage for management scenarios using representative softwood lumber mills from western (a) and eastern (b) Washington. Assumes all harvest is sawlog

3.2.2 Carbon Storage

One method of describing net carbon impacts of HWP is simply to track the embodied carbon of production, measuring the biogenic carbon stored in the product, and taking the difference between the two as the net carbon impact. For most wood products this value is negative. In other words, most HWP store more carbon than is emitted during production. This is shown in Table 11 for the first three life cycle stages, A1-Forestry operations, A2-Transportation of resources to manufacturing, and A3-Production of the wood product. The storage values are based on the oven dry density of the product with variations based on regional species mixes as reported by Puettmann 2024[8]. For the westside species mix the oven dry density is 495.23 kg/m3 and for the eastside species mix the oven dry density is 470.74 kg/m3. Figure 17 shows the relationship between embodied carbon, storage, and net carbon impacts graphically.

Table 11 Embodied carbon, carbon storage, and net carbon for softwood lumber produced from each for management scenario for west- and eastside Washington

A1-A3	Embodied Carbon	Storage	Net
Westside	**kg CO2e per m3 of product**		
PN/WC Final Harvest	66.22	(907.92)	(841.70)
AK Final Harvest	67.16	(907.92)	(840.76)
PN/WC/AK HT Managed	98.41	(907.92)	(809.51)
PN/WC/AK HT Unmanaged	100.50	(907.92)	(807.42)
PN/WC/AK LT Managed	104.08	(907.92)	(803.84)
PN/WC/AK LT Unmanaged	111.09	(907.92)	(796.83)
BAU PNW Final Harvest	73.81	(907.92)	(834.11)
Eastside	**kg CO2e per m3 of product**-		
IE/EC LT	40.88	(863.02)	(822.14)
BM LT	39.52	(863.02)	(823.50)
IE/EC/BM HT	38.70	(863.02)	(824.32)
IE/EC/BM Final Harvest	67.80	(863.02)	(795.22)
BAU INW Final Harvest	73.21	(863.02)	(789.81)

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[8] Puettmann, M. 2024. Cradle to grave life cycle assessment of North American Medium Density Fiberboard. https://www.compositepanel.org/wp-content/uploads/MDF-Cradle-to-grave-LCA-Final.pdf

(a)

Westside

(b)
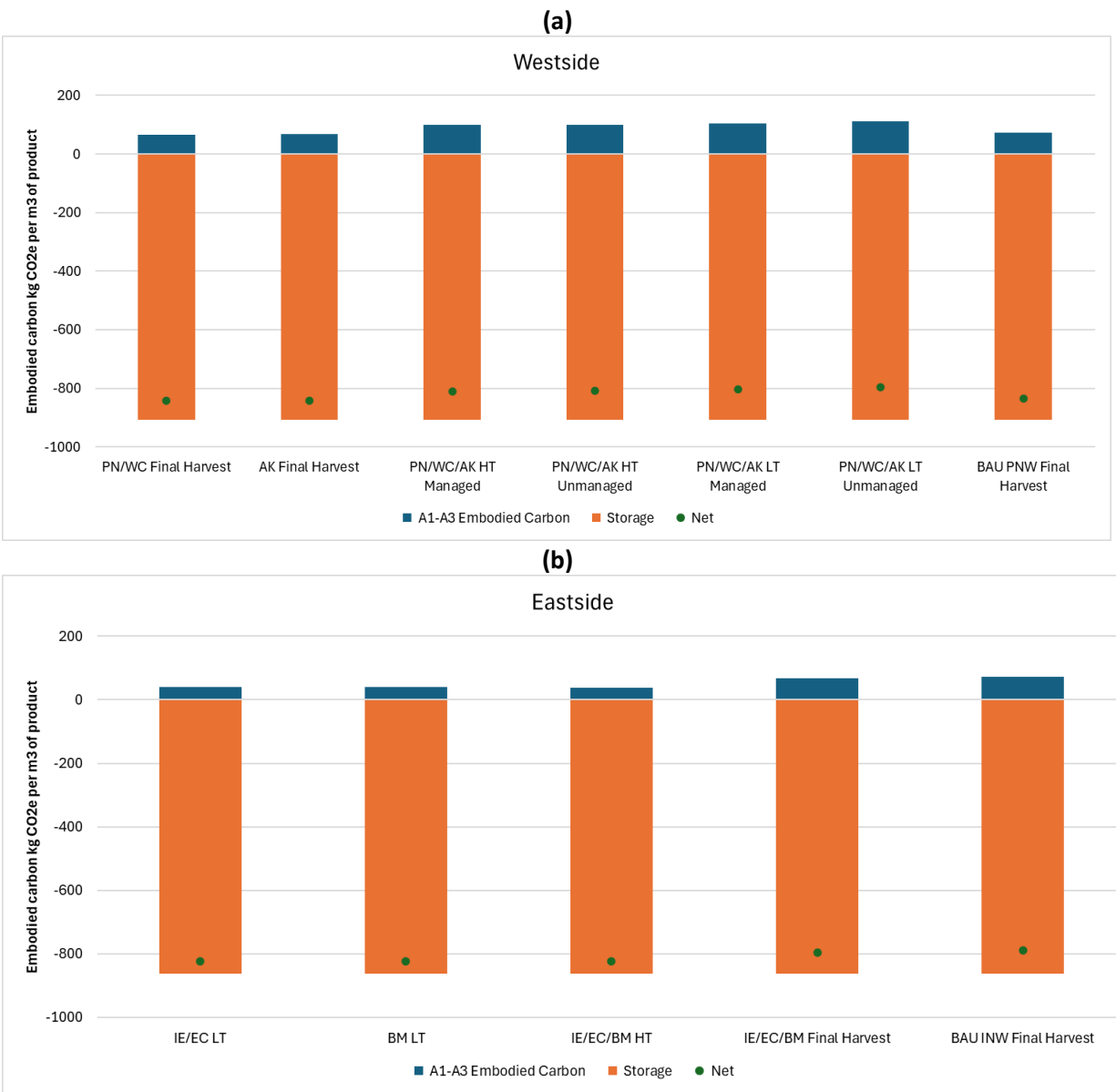
Eastside

Figure 17 Embodied carbon, carbon storage, and net carbon for softwood lumber produced from each for management scenario for westside (a) and eastside (b) Washington

The other method for describing the biogenic carbon flows for HWP follows ISO 21930. In this method it is assumed that all carbon removed from the atmosphere is eventually emitted back to the atmosphere as CO2. Therefore, the net carbon emission across the cradle-to-gate life cycle is zero. In this method, all carbon dioxide flows (kg CO_2e) presented in Table 12 are unallocated. These include byproducts produced and leaving the system boundary in module A3. They also include potential carbon waste at the end of life. Even though the system boundary for this LCA only includes modules A1-A3, in accordance with ISO 21930, emission from packaging (BCEK) is reported in A5-Construction and emission from the main product (BCEP) is reported in C3/C4-End-of-Life.

Using this method, the roundwood removed in the production of 1 m³ of softwood lumber from a BAU PNW scenario is shown in Table 7 (A1-Removals). The carbon storage in 1 m3 of softwood lumber is reported in C3/C4-End-of-Life products and byproducts column. The by-products produced during lumber production account for an additional carbon emission and are A3-Manufacturing. The combustion of wood fuel emitted as CO_2 is reported in A3.

Table 12. Biogenic Carbon Inventory Parameters for 1 m³ of Softwood Lumber, Unallocated. Example of BAU PNW

	A1	A2	A3	A5	C3/C4	Total
Removals [kg CO_2]	(1,725)	0.00	0.00	0.00	0.00	(1,725)
Product & Byproducts [kg CO_2]	0.00	0.00	572	0.00	908	1,471
Packaging removal [kg CO_2]			(1.72)			(1.72)
Packaging emission [kg CO_2]				1.72		1.72
Wood Combustion [kg CO_2]	0.00	0.00	254	0.00	0.00	254
Sum	(1,725)		824	1.72	908	0.00

3.3 Substitution Impacts

Combining the substitution factor with the carbon stored in wood products generates carbon displacement values as shown in Table 13 for wood versus steel studs and Table 14 for feedstocks used for MDF versus pulp and paper.

Assumptions:

- 100 percent of the feedstock to produce medium density fiberboard comes from lumber mill residues (chips and sawdust)
- 100 percent of the feedstock to produce pulp and paper comes from lumber mill residues (chips and sawdust)

3.3.1 Wood Stud vs. Steel Stud

In the case of the wood stud versus a steel stud, the comparison is easy because the steel stud stores zero carbon. The result is a net carbon storage for the wood stud and a net emission for the steel stud (Table 13). Three managed scenarios were selected from the westside to represent final harvest using the regional softwood lumber LCA model, and both heavy and light thinning operations from managed and unmanaged stands that would use the less 8-inch diameter representative Washington sawmill (westside). For all three scenarios, the wood wall has much lower embodied carbon results per square meter of wall, stores carbon in the wall, and displaces a significant amount of carbon by using wood (difference between net carbon stored in the wood wall minus the net carbon emission of the steel wall, Table 13).

Table 13 Substitution impacts for a wood stud versus a steel stud used in one square meter (m2) of wall area for the PN/WC Final Harvest, PN/WC/AK HT Managed, and PN/WC/AK LT Unmanaged

	Unit / m3	PN/WC Final Harvest	PN/WC/AK HT Managed	PN/WC/AK LT Unmanaged
Product mass, softwood lumber	kg	495.23	495.23	495.23
Embodied carbon	kg CO2$_{FOSSIL}$eq	66.22	98.41	111
Carbon storage	kg CO2 $_{BIOGENIC}$ eq	(907.92)	(907.92)	(907.92)
Net - carbon emissions	kg CO$_2$eq	(841.70)	(809.51)	(796.92)
Substitution Wall Components	**m2**	1.00	1.00	1.00
Softwood studs vs. Steel studs	**m2**	1.00	1.00	1.00
	Unit / m2	PN/WC Final Harvest	PN/WC/AK HT Managed	PN/WC/AK LT Unmanaged
Wood stud walls, mass	kg	10.40	10.40	10.40
Steel studs wall, mass	kg	4.15	4.15	4.15
Embodied carbon, wood wall	kg CO$_2$eq	1.39	2.07	2.33
Embodied carbon, steel wall	kg CO$_2$eq	17.97	17.97	17.97
Carbon storage, wood wall	kg CO$_2$eq	(19.07)	(19.07)	(19.07)
Carbon storage, steel wall	kg CO$_2$eq	-	-	-
Net carbon wood wall	kg CO$_2$eq	(17.68)	(17.00)	(16.74)
Net carbon steel wall	kg CO$_2$eq	17.97	17.97	17.97
Avoided emission by using wood wall over a steel wall	kg CO$_2$eq	(35.65)	(34.97)	(34.71)

Although differences were small between the three management scenarios, the displacement was greatest when considering only final harvest impacts (Figure 12). Managed stands also show a higher displacement than unmanaged stands. It is important to note that the emission from the steel stud cannot be recovered, so the carbon displaced (avoided emissions) accumulates overtime and therefore small differences between management scenarios can be significant over several rotations. See section 4.4.2 for a detailed example of the substitution benefit overtime.

(a)

PN/WC Final Harvest
Net Carbon Stored & Carbon Emissions Displaced
kg CO2e / m2 of Wall

(b)

PN/WC/AK HT Managed
Net Carbon Stored & Carbon Emissions Displaced
kg CO2e / m2 of Wall

(c)

PN/WC/AK LT Unmanaged
Net Carbon Stored & Carbon Emissions Displaced
kg CO2e / m2 of Wall
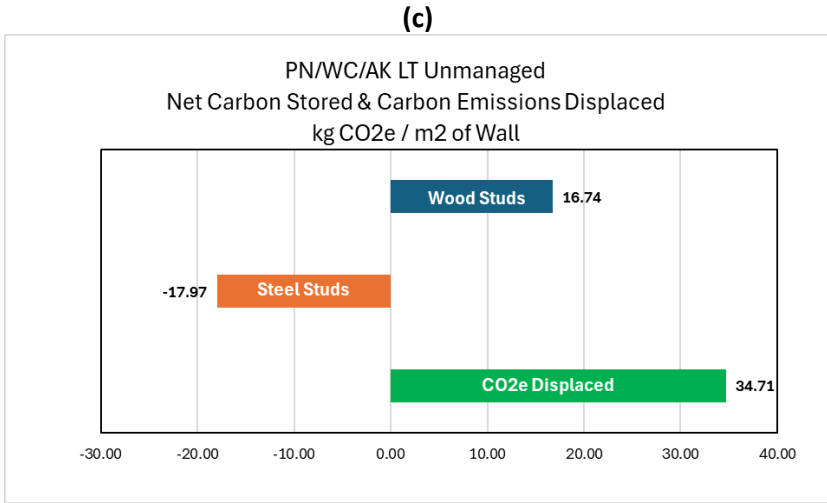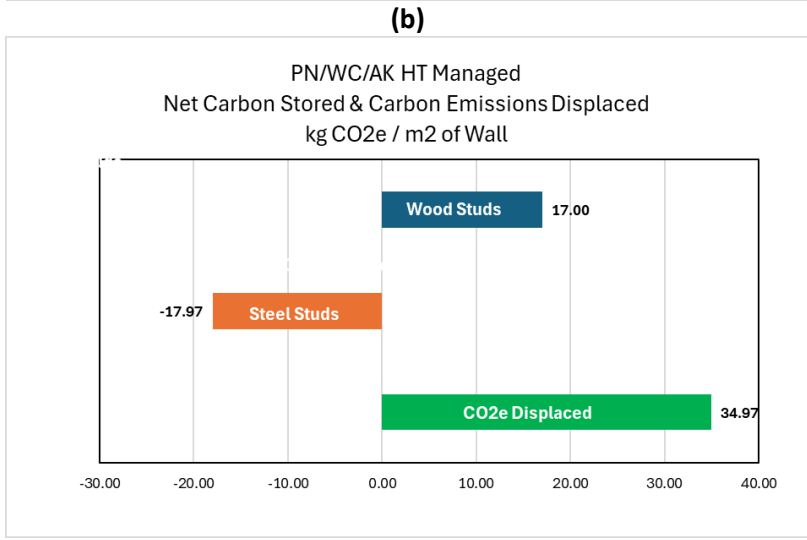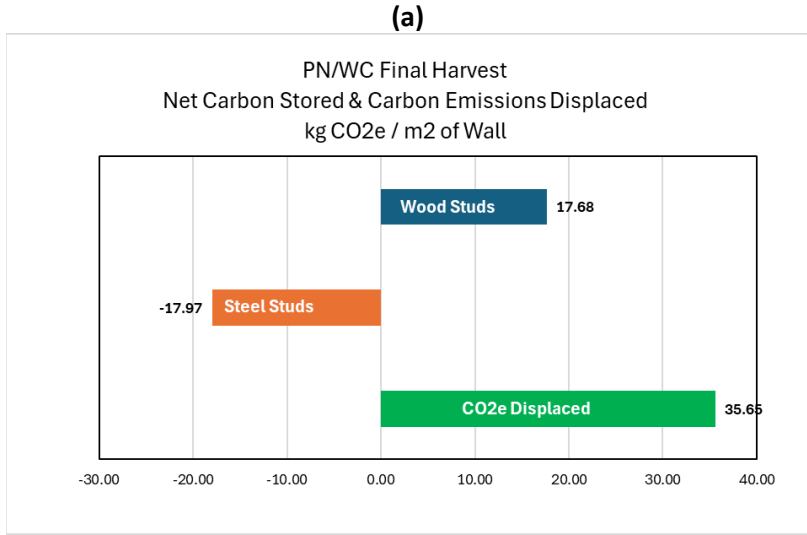
Figure 18 Comparison of the net carbon stored, emissions and carbon displaced for a wood stud versus a steel stud in one square meter of wall area for three management scenarios (a) PN/WC Final Harvest, (b) PN/WC/AK HT Managed, and (c) PN/WC/AK LT Unmanaged.

3.3.2 Incorporating Substitution and the Product Carbon Pools into Managed and Unmanaged Stands Carbon Outcomes

Incorporating forest carbon accumulation, short and long-term product stored carbon, and substitution outcomes that occur from a managing a given forested area, and examining the impact over several rotations shows the overall impact of managing forests and harvesting sustainably. Using a BAU PNW forestry model over six 45 year rotations, accounting for products, emissions, substitution, and biofuel displacement show a trend line of about 2.3 t C / ha / year ([Lippke et al. 2021](#))[9](Figure 13, adapted from Lippke et al. 2021). Comparing this trend line of carbon pools to high volume, but unmanaged forest (the solid brown line) shows:

- The sequestered carbon in unharvested forests reaches a limit as trees mature and the site reaches carrying capacity. Leaving unmanaged forests as legacies provides a one-time increase in C pools, with no opportunity for carbon benefit within the economy.

- Harvesting and replanting transfers carbon from the forest to products creating essential two carbon pools. This continued investment in forest management (this example 45 year rotation) stabilizes the product carbon pool (blue bars assuming a 90 year product life span for the solid wood products)

- Using wood products displaces emissions caused by functionally equivalent non-wood materials. Over the 6 rotations, these carbon pools can be significant as shown in the light green bars. These bars represent the avoided emissions from the production of steel studs.

- The carbon emissions from steel studs cannot be recovered, therefore the avoided emissions will accumulate with each subsequent rotation.

- In this example, including the avoided emissions increases the carbon pool by 45% compared to the carbon stored in the products alone.

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[9] Lippke, B., Puettmann, M., Oneil, E., & Dearing Oliver, C. (2021). The Plant a Trillion Trees Campaign to Reduce Global Warming – Fleshing Out the Concept. Journal of Sustainable Forestry, 40(1), 1–31. https://doi.org/10.1080/10549811.2021.1894951
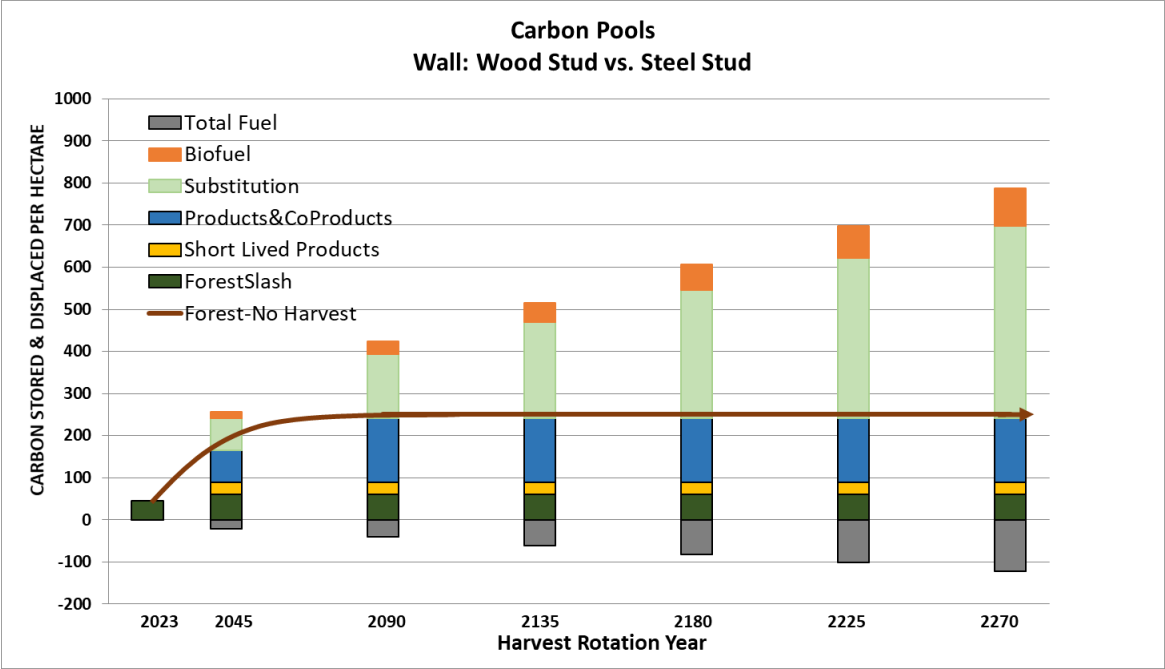
Figure 19 Carbon stored (y-axis) per hectare (ha) are stored and displaced over six 45- year rotations (x-axis) of sustainably managed Pacific Northwest forest beginning at year 2000. Forests that are harvested for products transfer stored C from the forest to long-lived products, coproducts, short-lived products, biofuels, and forest slash. Total fuel (grey bars) includes both biofuel (orange bars) and fossil fuel used in logging and product manufacture. Displaced carbon is shown in biofuel (proportion of harvested wood used in wood production) and substitution which accounts for the avoided emissions from the production of non-wood materials, in this case steel wall studs. End-of -life recycling is not included.

3.3.3 Medium Density Fiberboard vs. Paper

Similar substitution comparisons can be made for co-products from softwood lumber production. Here we examine the impacts of producing composite panels and pulp & paper. Since these products cannot share the same functional unit, they do compete for the same feedstock, mill residues. For this analysis analyze the difference in carbon impacts when the feedstocks are used for a long-lived product, such as MDF, versus a short-lived product like paper (Figure 14).
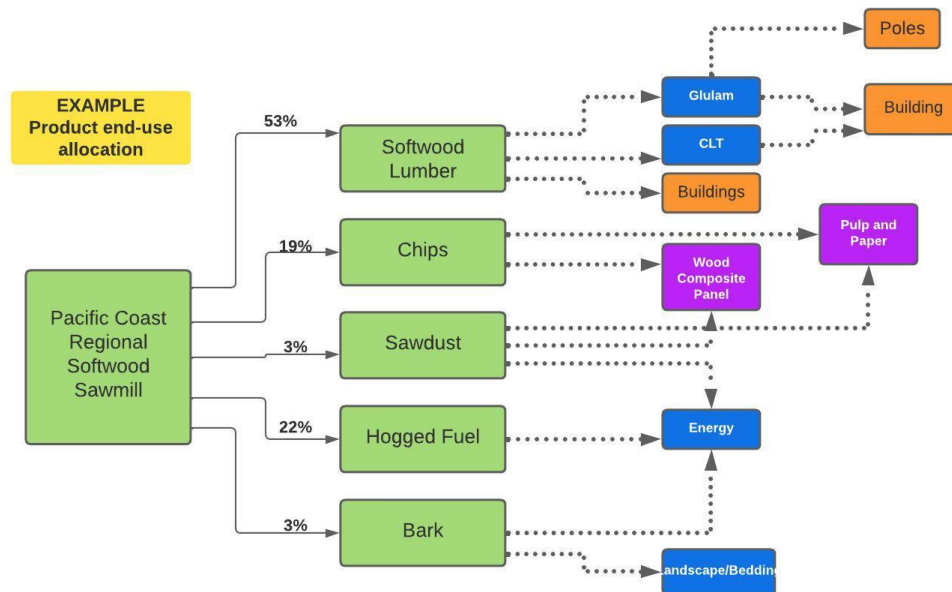
Figure 20 Allocation of wood flow from log to end use based on Puettmann 2024

Assumptions and calculations used for this comparison:

- Used the coproducts from the regional LCA sawmill model representing westside Washington
- 100 percent of the feedstock is from mill residues (chips and sawdust)
- It takes 774.59 kg of feedstock, unallocated, to produce 1 cubic meter of MDF
- 1 cubic meter of MDF, wood only = 654.37 kg
- 1.18 kg of feedstock for every kg of MDF produced
- It takes 1,283.52 kg of feedstock, unallocated, to product 861.83 kg of paper
- 1.49 kg of feedstock for every kg of paper produced
- Carbon content of feedstock is 50 percent
- Density used for feedstock is 450 kg/m3

The LCA model for MDF was performed using the default production of 1 cubic meter of finished product which contains 654.37 kg of wood. The paper production LCA model was analyzed on 1 kg of paper produced. The embodied carbon impact (kg CO2e) for each of these was then scaled to represent an equivalent feedstock input (Table 14). For the equivalent of a m3 of wood (450 kg input), the embodied carbon for MDF is 373 kg CO2e and 773 kg CO2e for paper (Table 14). In this case the long-lived product - MDF - has a lower embodied carbon (A1-A3) than paper and it stores the carbon out of the atmosphere over a longer time period (typically).

Table 14 Feedstock inputs, carbon storage, embodied carbon, and avoided emissions for production of medium density fiberboard (MDF) and paper on equivalent feedstock inputs

Equivalent Feedstock input		MDF	Paper
Wood input - Total	kg	450.00	450.00
Wood input - Total	m3	1.00	1.00
Embodied carbon A1-A3, scaled to 450 kg (1 m3) of feedstock input	kg CO2e	372.48	773.39
Carbon storage in Feedstock (allocated)	kg CO2eq	(825.00)	(825.00)
Net carbon	kg CO2eq	(452.52)	(51.61)
Avoided emission using feedstock for MDF over paper	kg CO2eq	504.13	

While end of life scenarios were not examined for this project, a recent report for the state of Minnesota (Zobel et al. 2024)[10] looked at paper, wood composite panels, and softwood lumber from cradle to grave under three different end of life scenarios. The Minnesota study has some relevance here based on the best path for feedstocks when the goal is to maximize carbon storage. Table 10 shows each product on an equivalent basis of 1 kg. Similar to Table 9, Table 15 shows paper production has a very high embodied carbon. The long term carbon benefits of long-lived products like wood composite panels and softwood lumber are further emphasized by their negative carbon storage under the landfill, recycle, and average end of life scenarios. Incineration at the end of life is the only scenario where no product is carbon is negative because the carbon contained in the product is instantly released in the atmosphere. Incineration can be improved when substitution is integrated into the analysis.

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[10] Zobel et al. 2024. Estimating current and future carbon stocks and emissions in Minnesota forests and forest products under multiple management scenarios. DRAFT report prepared for the Minnesota Forest Resources Council. 165pp.

Table 15 Summary of cradle-to-grave for selected products on a per kg basis over all End-of-Life (EoL) scenarios (Zobel et al. 2024)

	Paper	Wood composite Panels	Softwood lumber
From Zobel et al. 2024	**Embodied Carbon kg CO2e / kg of product**		
A1-A3 - Cradle-to-gate	1.7452	0.4115	0.1543
Cradle-to-grave			
A1-C4 - Landfill	4.5675	(0.8587)	(1.1159)
A1-C4 - Incineration	1.7838	0.4955	0.2383
A1-C4 - Recycle	1.7583		
A1-C4 - Average	2.9492	(0.6122)	(0.8694)
	Paper	**Wood composite Panels**	**Softwood lumber**
This study using regional LCA model (BAU PNW)	**Embodied Carbon kg CO2e / kg of product**		
A1-A3 Cradle to gate	1.560	0.7998	0.1212

4 Summary

When a tree is harvested for a sawlog, about half the biomass (below ground and tops, limbs and residues) associated with that tree is left in the forest to decay or provide habitat value. At the sawmill, logs used for lumber production are further allocated into the primary product (lumber) and byproducts (chips, sawdust, bark, hogged fuel). These allocations include the entire production chain where additional byproducts are produced during planning, trimming, sanding, and other product finishing operations. On a regional basis, the allocation to softwood lumber is approximately 53 percent with the remaining 47 percent is in the form of chips, sawdust, bark, hogged fuel, and shavings (Puettmann 2024). Many factors, not measured in this study, can influence this allocation such as log diameter (see Appendix 1) and milling equipment.

At each stage in processing carbon moves with the products and byproducts. During these transitions, materials, energy, and fuels needed for production of wood products are emitting carbon into the atmosphere through combustion or direct production emissions (embodied carbon). Tracing the carbon flows in the products and byproducts together with the embodied carbon created during processing is needed for full carbon accounting of any wood product. When the carbon is tracked from forest to product we can determine the net carbon benefits of harvested wood products. In addition, the carbon pools and flows that occur with downstream uses of byproducts can be significant and contribute significantly to the carbon pool for several decades depending on the end use.

Finally, the sustainable use of wood has significant carbon benefits over alternative materials. Sustainable rotational forest management provides the greatest volume biomass at the lowest embodied carbon. Leaving unmanaged forests as carbon sinks means that eventually the forest reaches its carrying capacity thus providing only a one time increase in carbon pools and no opportunity for additional carbon mitigation in product and substitution pools (Lippke et al. 2021). Using wood products displaces emissions caused by non-wood materials. The carbon emissions from non-renewable materials cannot be recovered and the displaced emissions (avoided emission) will accumulate with each harvest, increasing the carbon pool up to 45 percent compared to the carbon stored in the product along (Lippke et al 2021).

5 Abbreviations

CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
$CO2e_{BIOMASS}$	Carbon dioxide emissions from biomass combustion or decay emissions
$CO2e_{FOSSIL}$	Carbon dioxide emissions from fossil sources
$CO2e_{TOTAL}$	Sum of $CO2e_{BIOMASS}$ and $CO2e_{FOSSIL}$
EPD	Environmental Product Declaration
GWP	Global Warming Potential
GWP_{FOSSIL}	Global Warming Potential as an output from the TRACI impact methods. Does not include carbon dioxide released from biogenic sources, unit is $CO2e_{FOSSIL}$
$GWP_{BIOGENIC}$	Global Warming Potential released from the combustion of biogenic materials (e.g., wood) unit is $CO2e_{BIOGENICL}$
ISO	International Organization for Standardization
kg	Kilogram
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
m^3	Cubic Meters
MC	Moisture Content
MMT	million metric tons
Mt	metric tons
OD	Oven dry
Tkm	Metric-Tonne – Kilometers
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
BAU	Business as usual
TPO	Timber Product Output
LCI	Life cycle inventor
LCIA	Life cycle impact assessment
LCA	Life cycle assessment

6 Glossary

Embodied carbon - The embodied carbon is the global warming impact or all the greenhouse gas emissions through production of the product. Referred to as the global warming potential (GWP) based on the results from an accepted impact method e.g., TRACI. Embodied carbon <u>does not include </u>the carbon stored in the product. Embodied carbon <u>does not include </u>the CO2 released from biogenic sources, e.g., wood combustion. Embodied carbon <u>does include </u>other releases from biogenic sources, e.g., methane from wood combustion.

Carbon storage in wood measured in CO2– Carbon dioxide is not stored in wood; carbon is stored in wood. If that carbon were released into the atmosphere, it would combine with oxygen to form carbon dioxide. Carbon has a molecular weight of 12. Oxygen has a molecular weight of 16. Carbon dioxide has one carbon and two oxygens for a molecular weight of 44. For every 12 lbs of carbon stored in wood, there is an equivalent of 44 pounds of carbon dioxide that would otherwise occur in the atmosphere. We assume the carbon content of wood to be 50% of oven dry wood.

Net Carbon emission – this is the difference between carbon stored and carbon released (embodied carbon)

Substitution - This analysis can provide the estimated information on the emissions of wood products versus an equivalent alternative building material.

- How much carbon does the product store,
- What is the products embodied carbon,
- What is the displacement between the two?

Avoided emission for choosing to use a wood wall versus a steel wall is 11.41 kg CO2e/m2. This number does not consider carbon storage. These values are calculated by taking the absolute difference between the embodied carbon of wood wall and steel wall.

Displacement factor – This is also called a efficiency factor. It provides the avoided emissions for every unit of wood used. The displacement factor has not units as the kg CO2e cancel out (equation 1). Displacement factors make it possible to take the wood efficiency back to the acre. An example of this can be found below in Table 2 (extracted from Lippke et al.

$$\frac{[(GWP_{alt} - C\ storage_{alt}) - (GWP_{wood} - C\ storage_{wood})]}{C\ storage_{wood}}$$

Equation 1

7 Appendix 1 - Case Study – Using LCA to predict impacts based on log diameter

Softwood lumber production data that best represents manufacturing in western Washington was used as input into the life cycle assessment (LCA) models. Small-end log diameter was reported by species for roundwood input. These were grouped into four log diameter classes of less than 9-inchs, 9-10 inches, 12-14-inches, and greater than 30-inches. Log allocation to primary product and coproducts was based on mass allocation according to ISO 14040/14044 standards and the Product Category Rule for conducting LCAs and Environmental Product Declarations for structural wood products (UL 2018, 2020).

The lumber recovery factor (LRF) is a gauge of a sawmill's efficiency and is calculated by dividing the cubic foot volume of the logs processed by the nominal board footage of the lumber sawn. The LRF in board feet of lumber produced to cubic feet of roundwood input ranged from 4.34 to 10.38 BF Lumber/ft3 Logs (Table 16, Figure 21). The data shows that the larger LRFs are in the 9-10 inch small end diameter class with tapering lower as diameter increases and decreases (Figure 21). The lowest LRF is from the largest diameter class, and it is our conclusion that this representative facility is a larger log mill that has not updated processing to accommodate smaller diameter logs, but still produces dimension lumber. We will address the larger mill diameter class later in the report when the LCA results are presented. In a recent LCA study for the Pacific Coast softwood lumber production, the LRF was 9.3 BF lumber/ft3 logs (Puettmann 2024).

Table 16 Lumber Recovery Factor (LRF), board feet of lumber (BF) per cubic foot (ft3) log input from representative western Washington softwood lumber mills.

Log diameter, average small end	LRF BF Lumber/ft3 Logs
< 9 inches	
3.3 inches	6.37
5.5 inches	7.55
7.6 - 7.7 inches	9.77
9 inches	10.38
9-10 inches	
9.3 inches	10.38
10 inches	9.62
10 inches	9.16
12-14 inches	
12 inches	8.63
13 inches	8.93
30+ inches	
30-31 inches	4.34
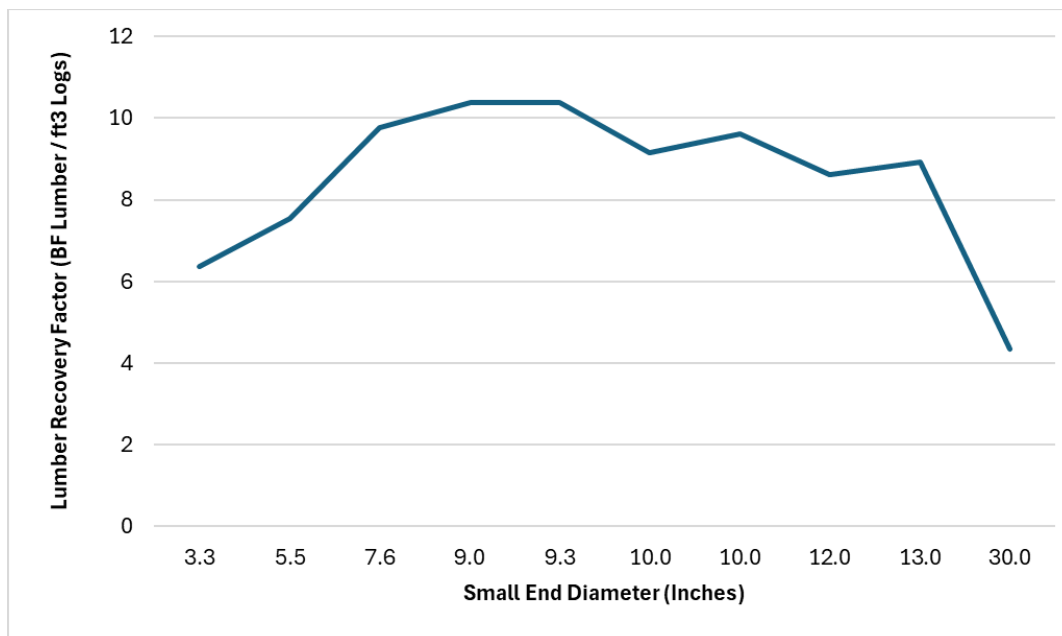
Figure 21 Lumber Recovery Factor (LRF), board feet of lumber (BF) per cubic foot (ft3) log input from representative western Washington softwood lumber mills.

The fraction of log cubic volume recovered as lumber is called the cubic recovery ratio (CRR). It is an accurate and consistent measure of the conversion efficiency used in scanners in sawmills to measure the log and lumber dimensions. As log diameter increases, the fraction of the log recovered as rough green lumber increases, and the fraction of by-products such as chips decreases while sawdust decreases. The CRR is a more common calculation used in LCA modeling. For the representative softwood producers for western Washington, the CRR ranged from 0.46 to 0.68. The CRR for Pacific Coast sawmills was 0.497 m^3_{lumber}/m^3_{log}. The correlation between log diameter and CRR was not as linear as seen for LRF (Table 12). This could be due to each facility's unique processing machines which have different saw kerfs, saw types, and lumber grade targets (Table 1, Figure 2). As expected the largest recovery ratio was in the larger log diameter, where a larger proportion of lumber was produced from the log (68%).

BAU for the Pacific Northwest

Since the mill production data for softwood lumber had some granularity for log diameter size, LCA models were developed using these mill production data and the average Pacific Northwest (PNW) Forestry LCA (Oneil and Puettmann 2017) to examine the trade-offs between log size and lumber recovery in LCA.

The PNW forestry model encompasses western Oregon and Washington demarcated by the Cascade Mountain crest. Softwood lumber facilities report a range of average diameter distributions (Table 17). These can be used to estimate wood and carbon mass values for inputs and outputs per cubic meter of lumber by average scaling diameter.

Table 17 shows that the 9-10 inch diameter class requires the highest log volume input (2.18 m3, 0.46 CRR) to produce a cubic meter of lumber while the largest diameter class of 30+ inches requires the

lowest, 1.48 m3 (0.68 CRR) (Figure 22). For LCA modeling using a mass allocation, the mill production inputs such as heat energy and fuels are allocated to the lumber based on the CRR. The remainder of the log is allocated to byproducts which can either be used onsite for energy generation (displacing the use of fossil fuels), sold to composite panel producers (long term product), or sold for short term products such as pellets or pulp. Like lumber, the carbon in the log input is transferred within the byproducts to the next use.

Table 17 Per cubic meter of lumber production reported in volume and mass and carbon storage for each diameter log class.

	Units/per m3	<9"	9-10"	12-14"	>30"
Lumber Output	m3	1	1	1	1
Lumber Output	kg	495	495	495	495
C Storage in Lumber	kg CO2e	907.92	907.92	907.92	907.92
Log Input	m3	1.74	2.18	2.00	1.48
Log Input	kg	861.20	1,079.60	991.45	733.93
C Storage in Log	kg CO2e	1,578.88	1,979.27	1,817.66	1,345.54
CRR		0.58	0.46	0.50	0.68
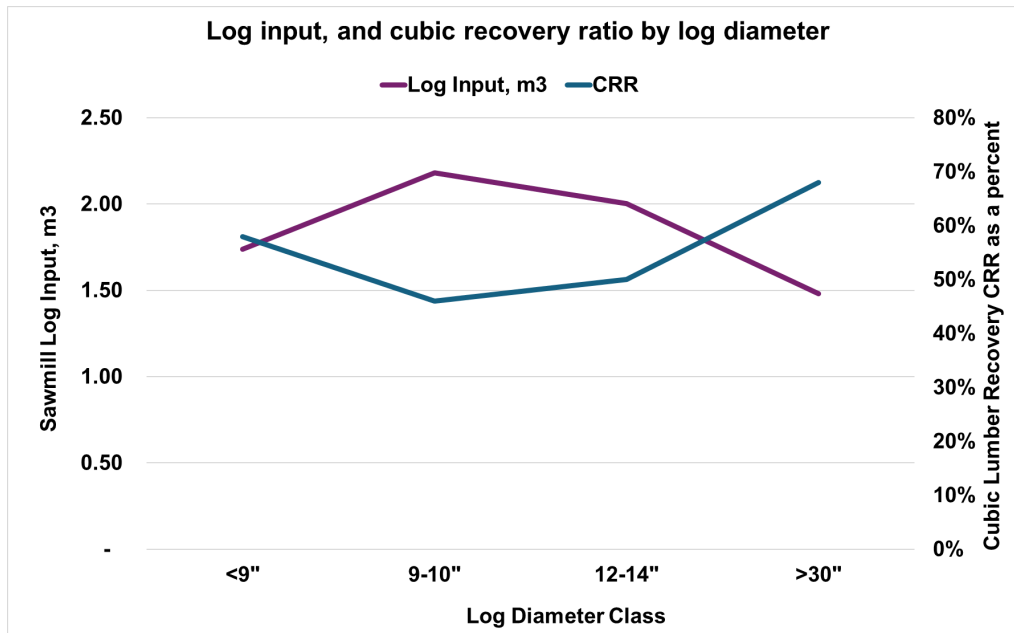
Figure 22 The correlation between log input, log diameter class, and cubic recovery ratio (CRR) from representative western Washington softwood lumber mills.

When we connect the LCA results with log diameter, CRR, and carbon storage we find that CRR has a direct correlation with the LCA results (Figure 23). These differences arise because with a high CRR, a higher proportion of the log is processed into lumber versus byproducts. Because each material carries as its embodied carbon its proportion of the mill's inputs (i.e., energy), lumber for high CRR mills carries

a bigger embodied carbon footprint. One other important note is the larger diameter facilities (30+ inches) had proportionally higher energy use (electricity). We don't know but can speculate that the equipment might be older and less energy efficient. ***NOTE: This type of information was not available for this study, and this relationship may not be true for all larger diameter sawmills***.

The nuances explored here add granularity to the story of the carbon dynamics of producing HWP. They also have a direct impact on the discussion around growing trees longer, and therefore producing larger diameter logs. Though longer rotations may produce more wood – assuming good management techniques, excellent timing, and luck - longer rotations may not show as significant of a carbon benefit as expected when incorporated into a framework of HWP accounting that meets international standards.
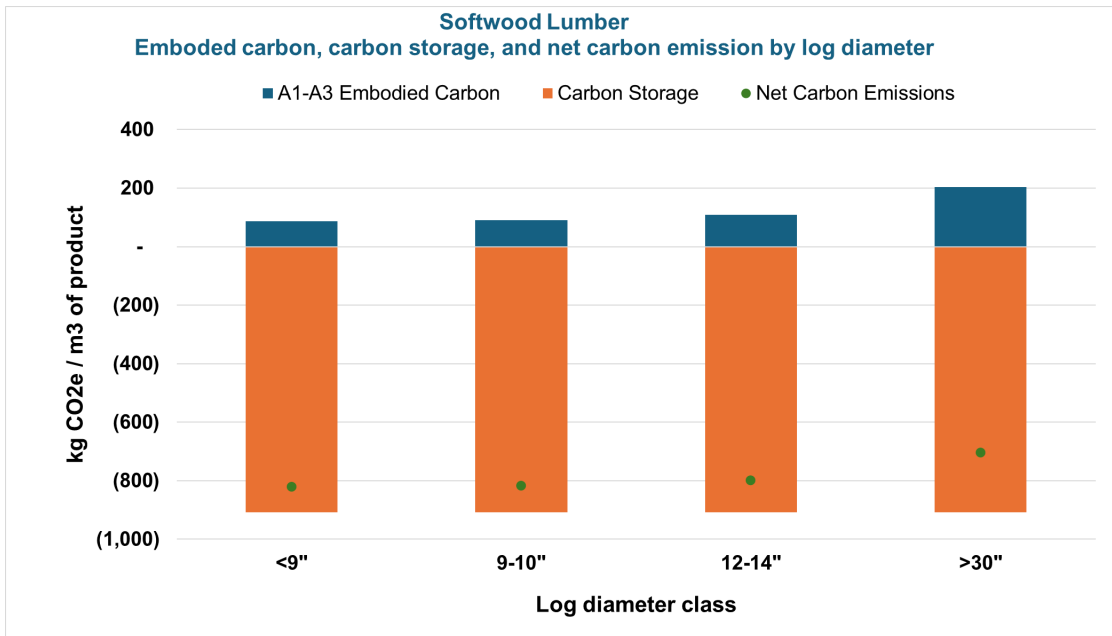
Figure 23 Relationship between embodied carbon, carbon storage, and diameter class for representative western Washington softwood lumber mills, using the BAU PNW forestry model (Oneil and Puettmann 2017)

8 Appendix 2 Supporting Figures and Tables
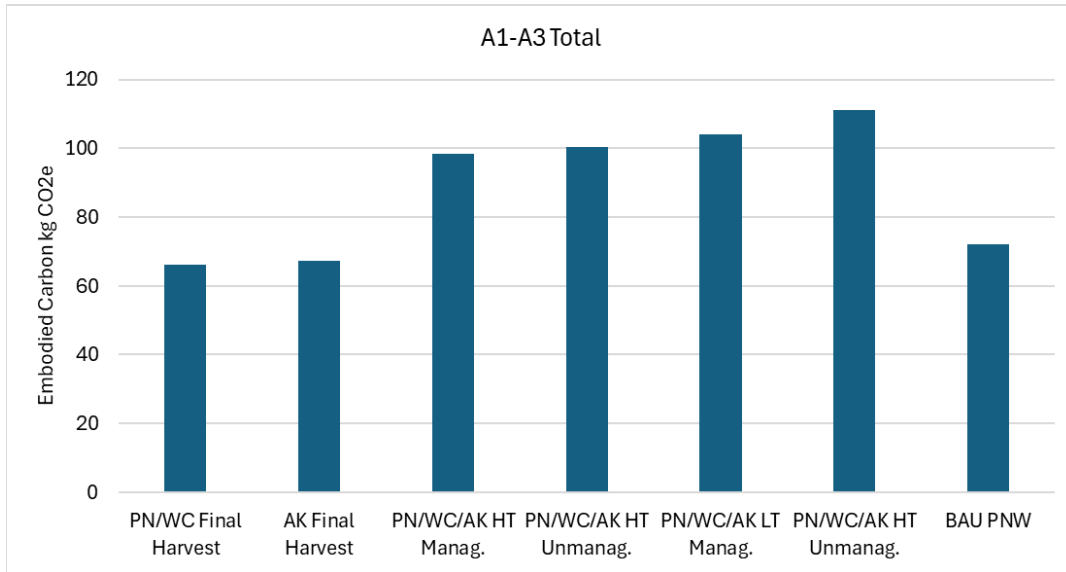
Figure 24 Total A1-A3 Embodied Carbon for three final harvest scenarios and four management scenarios using representative softwood lumber mills from western Washington. Assumes all harvest is sawlog.
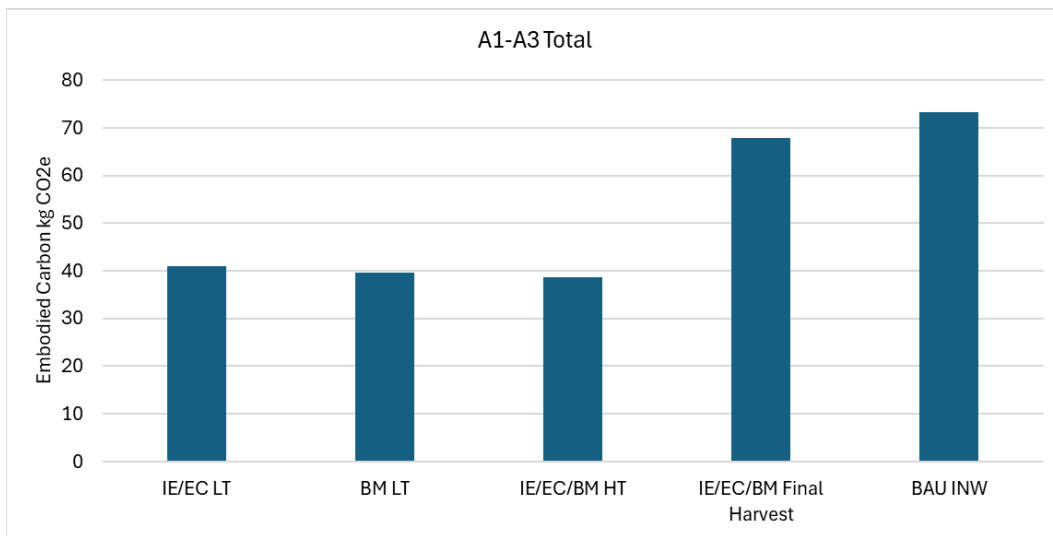
Figure 25 Total A1-A3 Embodied Carbon for three final harvest scenarios and four management scenarios using representative softwood lumber mills from eastern Washington. Assumes all harvest to sawlog.

Table 18: Distribution of estimated yield by scaling diameter – westside final harvests by subregion and major species.

Westside Yield (cf/ac) by Scaling (small end) Diameter for Final Harvests: SFLO									
Westside conifer									
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
PN	4%	23%	22%	21%	16%	8%	5%	1%	9,855
WC	3%	19%	13%	14%	15%	12%	14%	9%	9,663
* no SFLO plots in AK variant.									
Westside hardwood									
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
PN	7%	36%	26%	17%	7%	5%	2%	0%	5,147
WC	7%	42%	28%	17%	5%	1%	1%	0%	6,102
Westside WRC									
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
PN	4%	33%	22%	12%	14%	6%	6%	3%	6,415
WC	3%	32%	22%	11%	26%	2%	1%	3%	6,090

Table 19: Distribution of estimated yield by scaling diameter – westside heavy thin by subregion and major species.

Westside Yield (cf/ac) by Scaling (small end) Diameter for Heavy Thin Harvests: SFLO									
Westside conifer									
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
PN	10%	39%	29%	16%	5%	1%	0%	0%	7,788
WC	23%	72%	5%	0%	0%	0%	0%	0%	3,667
* no SFLO plots in AK variant.									
Westside hardwood									
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
PN	11%	48%	30%	9%	2%	0%	0%	0%	5,105
WC	12%	61%	28%	0%	0%	0%	0%	0%	4,694
Westside WRC									
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
PN	10%	72%	19%	0%	0%	0%	0%	0%	4,016
WC	10%	73%	18%	0%	0%	0%	0%	0%	3,008

Table 20: Distribution of estimated yield by scaling diameter – westside light thin by subregion and major species.

Westside Yield (cf/ac) by Scaling Diameter for Light Thin Harvests: SFLO								
Westside conifer								
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
PN	29%	71%	0%	0%	0%	0%	0%	0%	3,972
WC	27%	73%	0%	0%	0%	0%	0%	0%	6,762
* no SFLO plots in AK variant.								
Westside hardwood								
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
PN	31%	69%	0%	0%	0%	0%	0%	0%	11,192
WC	24%	76%	0%	0%	0%	0%	0%	0%	486
Westside WRC								
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
* none removed under light thinning conditions								

Table 21: Distribution of estimated yield by scaling diameter – eastside final harvests by subregion and major species.

Eastside Yield (cf/ac) by Scaling Diameter for Final Harvests: SFLO

Eastside conifer

FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
BM	7%	31%	39%	19%	3%	0%	0%	0%	3,781
EC	7%	28%	30%	19%	10%	4%	2%	1%	5,016
IE	8%	29%	33%	21%	8%	2%	0%	0%	5,666

Eastside hardwood

FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
EC	14%	44%	20%	8%	5%	3%	2%	4%	2,048
IE	11%	37%	25%	12%	15%	0%	0%	0%	1,701

Eastside WRC

FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
EC	2%	12%	16%	18%	21%	13%	12%	6%	4,038
IE	9%	39%	30%	10%	12%	0%	0%	0%	2,757

Table 22: Distribution of estimated yield by scaling diameter – eastside heavy thin by subregion and major species.

Eastside Yield (cf/ac) by Scaling Diameter for Heavy Thin Harvests: SFLO								
Eastside conifer								
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
EC	17%	54%	27%	1%	0%	0%	0%	0%	3,781
IE	13%	42%	37%	8%	0%	0%	0%	0%	5,016
Eastside hardwood								
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
EC	24%	61%	15%	0%	0%	0%	0%	0%	3,070
IE	20%	63%	17%	0%	0%	0%	0%	0%	1,864
Eastside WRC								
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
EC	27%	73%	0%	0%	0%	0%	0%	0%	260
IE	14%	55%	29%	2%	0%	0%	0%	0%	2,276

Table 23: Distribution of estimated yield by scaling diameter – eastside light thin by subregion and major species.

Eastside Yield (cf/ac) by Scaling Diameter for Light Thin Harvests: SFLO									
Eastside conifer									
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
EC	17%	54%	27%	1%	0%	0%	0%	0%	4,587
IE	13%	42%	37%	8%	0%	0%	0%	0%	6,455
Eastside hardwood									
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
IE	36%	64%	0%	0%	0%	0%	0%	0%	262
Eastside WRC									
FVS Variant	Avg 4_6 SED	Avg 6_8 SED	Avg 8_12 SED	Avg 12_16 SED	Avg 16_20 SED	Avg 20_24 SED	Avg 24_30 SED	Avg >30 SED	total volume removed
IE	16%	54%	31%	0%	0%	0%	0%	0%	5,214
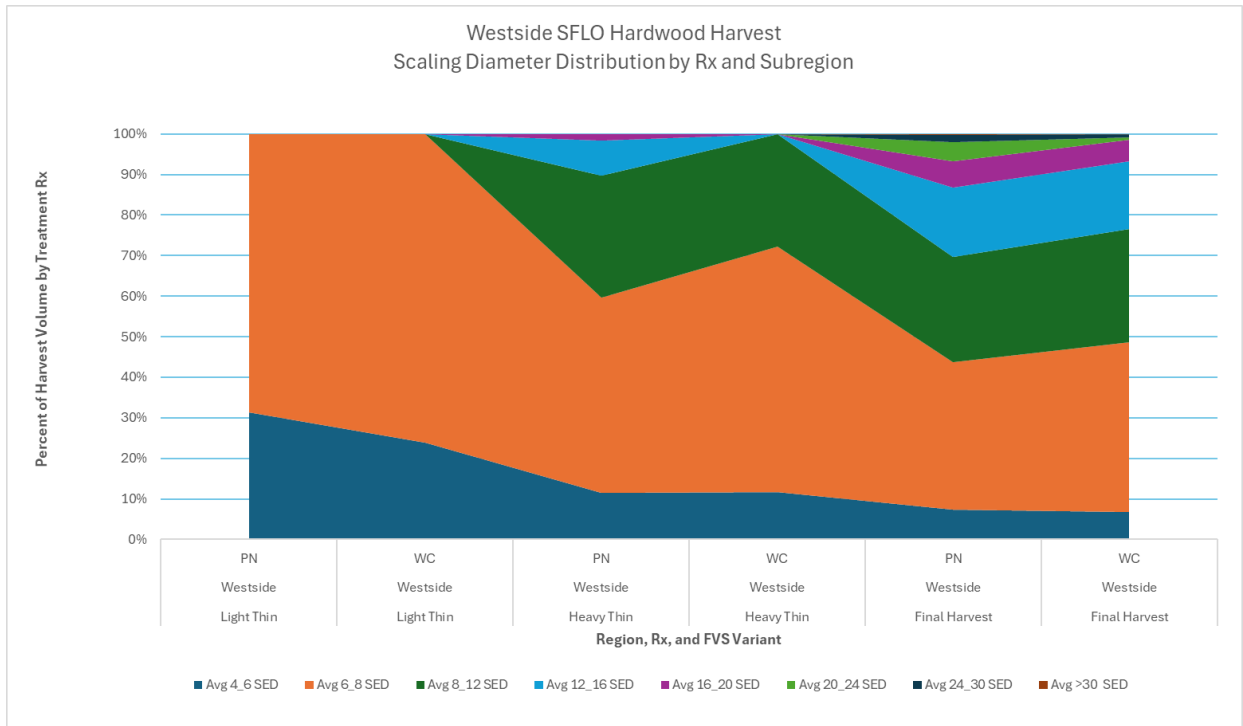
Figure 26: Westside Scaling Diameter by Prescription, Subregion, and Treatment for Hardwood Dominated Stands – SFLO
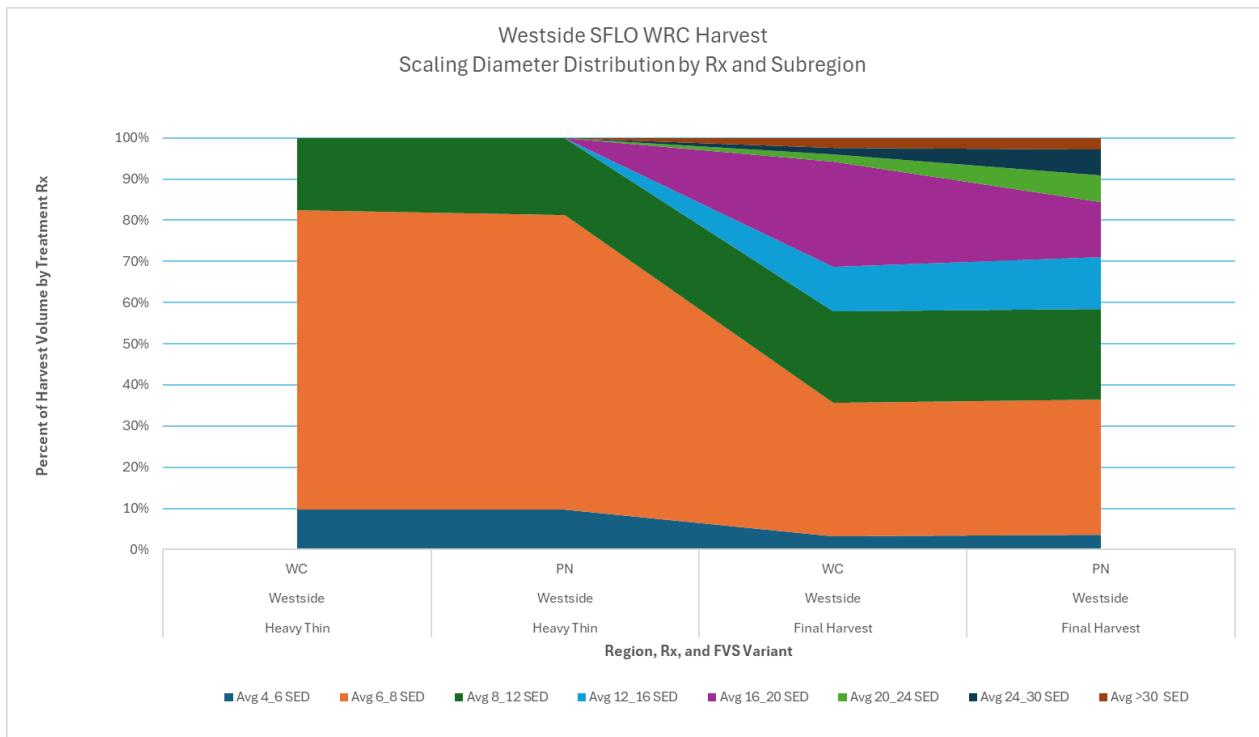
Figure 27: Westside Scaling Diameter by Prescription, Subregion, and Treatment for Western Redcedar Stands – SFLO
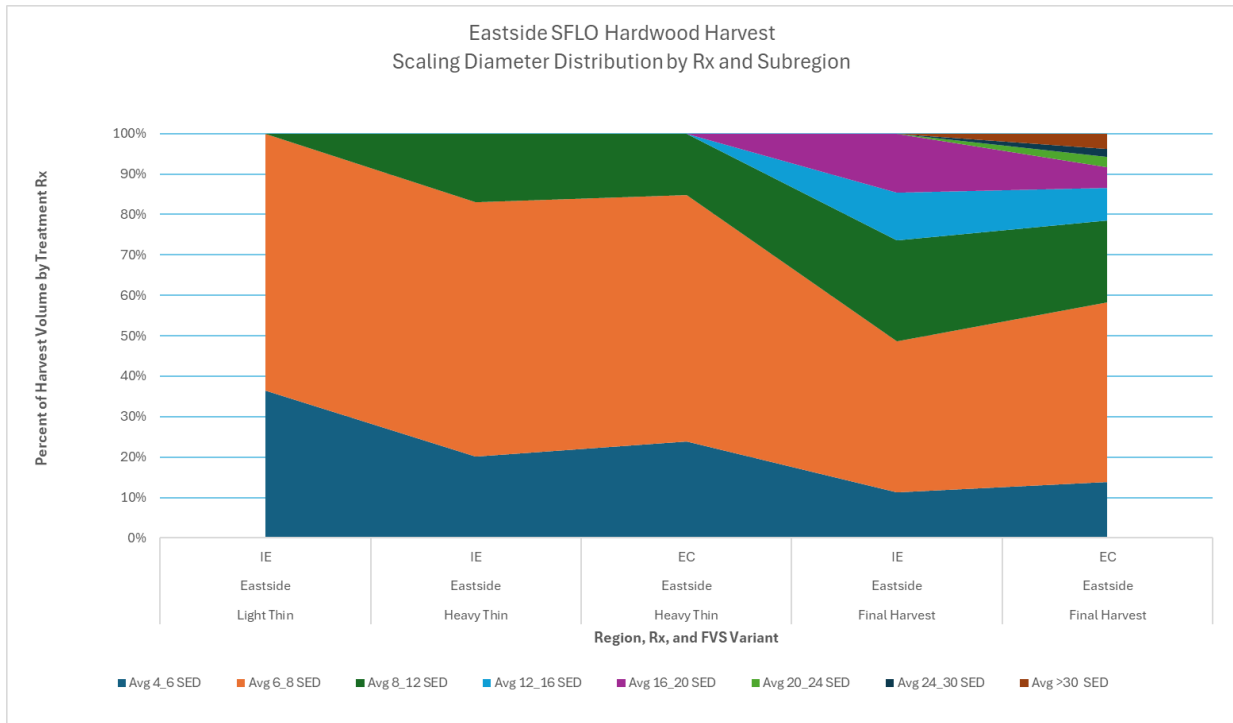
Figure 28: Eastside Scaling Diameter by Prescription, Subregion, and Treatment for Hardwood Dominated Stands – SFLO
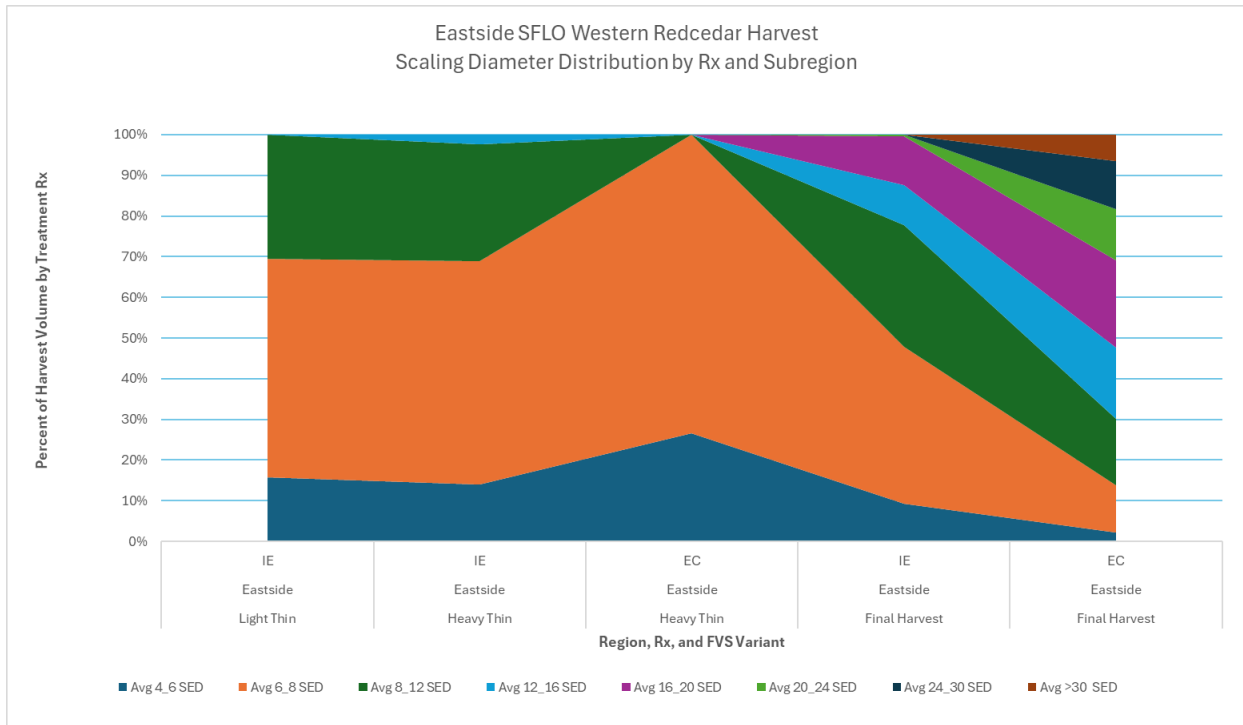
Figure 29: Eastside Scaling Diameter by Prescription, Subregion, and Treatment for Redcedar Dominated Stands – SFLO

Appendix 3: Carbon Market Standards and Status

Forest Carbon Offset Methodology Comparison

The table below outlines key differences and project design elements in the ACR voluntary forest carbon offset methodology and Washington's compliance Forest Offset Protocol (FOP).

	ACR	WA FOP
Start Date	The date the project was submitted to ACR for listing review or other options listed in the ACR Standard (see Appendix A). Must be validated within 3 years of start date.	The date on which the earliest activity is first implemented, which can include submitting the project listing information.
Crediting Period	20 years for all IFM projects	25 years for all IFM projects
Minimum Project Term	40 years for all AFOLU projects	125 years: Projects must be monitored for 100 years after the final crediting period
Land Eligibility	Non-federal forestland in the U.S. that can be legally harvested with greater than 10% tree canopy cover.	Non-federal forestland with greater than 10% tree canopy cover.
Natural Management Requirements	Use of non-native species is specifically prohibited.	Requirements for native species and species diversity - see natural forest management criteria outlined below. No broadcast fertilization.
Forest Certification	Required: SFI, FSC, or ATFS	Required: SFI, FSC, or ATFS
Monitoring and Reporting	Required to complete and submit a Monitoring Report at each verification event, at minimum every 5 years during a crediting period.	Required to complete and submit an Annual Report during a crediting period.
Full Verification	Every 5 years	Every 6 years
Re-inventory requirements	At least every 10 years	At least every 12 years

Permanence	Sign a Reversal Risk Mitigation Agreement – Contribute to a buffer pool based on ACR tool. Update ACR tool to determine buffer pool contribution every 5 years at verification events.	Monitor all onsite carbon stocks, submit annual Offset Project Data Reports, undergo third-party verification of reports with site visit at least every six years for the duration of the project life. All intentional reversals must be compensated through retirement of other compliance instruments. Maintain a forest buffer account to provide insurance against unintentional reversals. Quantity contributed to buffer account determined by a project's reversal risk rating and is recalculated at every verification.
Real	No crediting of a projected stream of offsets on an ex-ante basis ("before it occurs").	No crediting of a projected stream of offsets on an ex-ante basis ("before it occurs").
Additional	Exceeds regulatory/legal requirements. Goes beyond common practice. Overcomes at least one of three implementation barriers: institutional, financial, or technical.	Demonstrated via a legal requirements test and a performance standard evaluation. IFM projects automatically satisfy the performance standard evaluation with the baseline estimation requirements.
Leakage	Market leakage: determined by default market leakage discount factors in methodology (40% under current PSE project) Activity shifting: no leakage beyond de minimum allowed.	Market leakage: Considers a market leakage deduction of 20%, applied to the carbon stored in wood products. Activity shifting leakage: Called "Secondary Effects" and quantifies different in actual versus baseline harvest. Leakage is a 20% deduction if actual harvest is less than baseline harvest.
Environmental & Community Assessments	Must develop and disclose an impact assessment to ensure compliance w/ environmental and community safeguards best practices.	No specific requirement
Aggregation/Group Projects	Yes.	Yes; however, project area may not extend more than two adjacent ecosections or supersections.

Sustainable Development/ SDGS	Projects must disclose negative impacts to SDGs, but no particular tool or protocol.	No specific sustainability objective.
SDG Requirements	Project must report on any impacts associated with relevant SDGs at each Reporting Period. Also, ACR can be combined with the Climate Community and Biodiversity Alliance (CCBA) Standard.	No specific SDG requirements
Unintentional Reversal	Buffer pool covers the reversal if loss amount is less than project contribution. If the loss amount is greater than the project contribution, project proponent is required to pay a deductible of 10% of the loss amount in addition to surrendering its buffer pool contribution up to the point of the loss.	Buffer pool covers the losses due to unintentional reversals. Project automatically terminates if an unintentional reversal occurs that reduces carbon stocks below baseline levels.
Intentional Reversal	Project proponent must replace the total loss amount to the Buffer Pool Account.	Forest owner must submit to ARB for placement in the Retirement Account a quantity of valid ARB offset credits equal to the number of credits reversed.
Automatic Termination	Project stocks drop decrease below baseline levels prior to the end of the Minimum Project Term.	Project automatically terminated if: An unintentional reversal occurs that reduces the project's carbon stocks below the baseline. The project is sold to an entity that does not elect to take over the project. This requires the project to retire credits to compensate for termination. A project may voluntarily terminate prior to the end of the minimum time commitment if the required quantities of compliance instruments are retired.

Improved Forest Management Project
Meeting Washington Forest Offset Protocol Eligibility Requirements

For a project to be registered under Washington's Department of Ecology Forest Offset Protocol [1], it must meet the stated eligibility requirements. The relevant requirements for forest landowners are summarized below.

Eligible Activities Under IFM Projects

The following types of forest management activities are eligible under IFM projects:

Forest IFM projects that involve management activities that maintain or increase carbon stocks on forested land relative to baseline levels of carbon stocks as defined in subchapter 5.2 of the Forest Offset Protocol (FOP).

(a) Eligible management activities may include, but are not limited to:

(1) Increasing the overall age of the forest by increasing rotation ages;

(2) Increasing the forest productivity by thinning diseased and suppressed trees;

(3) Managing competing brush and short-lived forest species;

(4) Increasing the stocking of trees on understocked areas; and/or

(5) Maintaining stocks at a high level.

(b) The project area for an improved forest management project:

(1) Must be finalized by the conclusion of the initial verification;

(2) May be situated on either private or public lands, excluding federal lands that are not included in the categories of land listed in subchapter 3.2(f) of this protocol;

(3) Must be situated on land that has greater than 10 percent tree canopy cover;

(4) May define geographic boundaries such that non-forested areas or areas not under forest management are excluded from the project area;

(5) Can be contiguous or separated into tracts;

(6) May extend across multiple assessment areas within an ecosection or supersection, but may not extend across more than two adjacent ecosections or supersections as identified in the supersection maps available from the Forest Offset Protocol Resources section of ARB's website; and

(7) May not include land that is subject to a conservation easement with federal holders.

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[1] https://ww3.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf

Project Eligibility

1) Meet Natural Forest Management Criteria – these criteria are detailed in Table 3.1 of the FOP. Key elements of these criteria are:

a) <u>Native Species</u> - project must contain at least 95% native species based on the sum of carbon in standing live tree carbon stocks or must be show continuous progress toward meeting this requirement and must meet the criterion with 25 reporting periods.

b) <u>Mixed Species Distribution</u> - Where the project area naturally consists of a mixed species distribution, no single species' prevalence, measured as the percent of the basal area of all live trees in the project area, exceeds the percentage value of standing live tree carbon shown under the heading "Species Diversity Index" (SDI) in the Assessment Area Data File available on the Forest Offset Protocol Resources section of ARB's website.

Project must demonstrate continuous progress towards meeting requirement and must meet criterion within 25 reporting periods. Project is not eligible unless it is demonstrated that management activities will enable this goal to be achieved within 25 reporting periods. Projects must continue to meet requirements for the duration of the project life.

c) <u>Distribution of Age Classes/Sustainable Management</u> - All forest landholdings within geographic areas eligible under this protocol (the contiguous United States and eligible portions of Alaska), including the project area, owned or controlled by the forest owner(s) and its affiliates (as defined in subchapter 3.1(a)(2)) are currently under one or a combination of the following:

i. Third-party certification under the Forest Stewardship Council, Sustainable Forestry Initiative, or Tree Farm System, whose certification standards require adherence to and verification of harvest levels which can be permanently sustained over time, or

ii. Operating under a renewable long-term management plan that demonstrates harvest levels which can be permanently sustained over time and that is sanctioned and monitored by a state or federal agency, or

iii. The forest owner(s) must employ uneven-aged silvicultural practices and canopy retention averaging at least 40 percent across the forest, as measured on all contiguous 20-acre areas within the entire forestland owned by the forest owner(s), including land within and outside of the project area. (Areas impacted by Significant Disturbance may be excluded from this test.)

iv) <u>Even-Aged Management</u> - If even-aged management is practiced, on a watershed scale up to 10,000 acres (or the project area, whichever is smaller), projects must maintain no more than 40 percent of their forested acres in ages less than 20 years. (Areas impacted by Significant Disturbance may be excluded from this test.)

Project must demonstrate continuous progress towards meeting requirement and must meet criterion within 25 reporting periods. Project is not eligible unless it is demonstrated that management activities will enable this goal to be achieved within 25 reporting periods. Projects must continue to meet requirements for the duration of the project life.

v) <u>Structural Elements (Standing and Lying Dead Wood)</u> - For portions of the project area that have not recently undergone salvage harvesting:

If a verifier determines that the quantity of lying dead wood is commensurate with recruitment from standing dead trees (i.e., there is no evidence that lying dead wood has been actively removed), the project must maintain (or demonstrate ongoing progress toward) an average of at least: one (1) metric ton of carbon (C) per acre; or 1% of standing live tree carbon stocks, in standing dead tree carbon stocks, whichever is higher.

If a verifier determines that the quantity of lying dead wood is not commensurate with recruitment from standing dead trees (i.e., it appears lying dead wood has been actively removed), the project must maintain (or demonstrate ongoing progress toward) an average of at least: two (2) metric tons of carbon (C) per acre; or 1% of standing live tree carbon stocks, in standing dead tree carbon stocks, whichever is higher.

Standing dead tree carbon stocks may be evenly or unevenly distributed throughout the portion of the project area unaffected by salvage harvesting, as long as the appropriate minimum average tonnage per acre requirement is met.

Portions of the project area that have not recently undergone salvage harvesting must demonstrate continuous progress towards meeting requirement and must meet criterion within 25 reporting periods. Project is not eligible unless it is demonstrated that management activities will enable this goal to be achieved within 25 reporting periods. Projects must continue to meet requirements for the duration of the project life.

2) Maintain or increase standing live tree carbon stocks within the project area over any 10 consecutive year period during the project life except as allowed for subchapter 3.1(b)(1).

3) If the project employs even-aged management practices within the project area, it must meet the following harvest unit size and buffer area requirements:

(A) Even-aged harvest units must not exceed 40 acres in total area;

(B) Even-aged harvest units shall be separated by an area that is at least as large as the area being harvested or 20 acres, whichever is less, and shall be separated by at least 300 ft. in all directions;

(C) Within ownership boundaries, no area contiguous to an even-aged harvest unit may be harvested using an even-aged harvest method unless the average of the dominant and codominant trees on an acceptably stocked prior even-aged harvest unit is at least five feet tall, or at least five years of age from the time of establishment on the site, either by the planting or by natural regeneration. If these standards are to be met with trees that were present at the time of the harvest, there shall be an interval of not less than five years following the completion of operations before adjacent even-aged management may occur;

(D) An area on which even-aged timber operations have taken place shall be classified as acceptably stocked if either of the standards set forth in 1. or 2. below are met:

1. An area contains an average point count of 150 per acre that meets the requirements of subchapter 8.1(b)(2)(E) to be computed as follows:

> a. Each countable tree which is not more than 4 inches DBH counts 1 point;
> b. Each countable tree over 4 inches and not more than 12 inches DBH counts 3 points; and
> c. Each countable tree over 12 inches DBH counts as 6 points.

2. The average residual basal area measured in stems 1 inch or larger in diameter is at least 50 square feet per acre; and

(E) Cuts on harvest units that occurred prior to the project commencement date are exempt provided that no new harvests occur in the previously cut harvest unit or would-be buffer area until the harvest unit cut prior to project commencement meets the requirements of subchapter 3.1(a)(4)(A) and 3.1(a)(4)(B).

VERRA Standards

VM0045 Methodology for Improved Forest Management Using Dynamic Matched Baselines from National Forest Inventories, v1.0, Oct 2022, https://verra.org/methodologies/methodology-for-improved-forest-management/

> This methodology is applicable to a wide range of improved forest management (IFM) practices and uses a dynamic performance benchmark for additionality and the crediting baseline created from national forest inventories. Eligible projects must adopt one or more specific, non-pre-existing, IFM practices. The focus of accounting is on estimation of GHG emissions and/or carbon stock change on permanent plots, not on estimation of stocks per se, therefore improving the precision of reported GHG emission reductions and/or removals. The methodology employs a broad monitoring and accounting framework that captures the GHG impacts of IFM practices aimed at avoiding emissions (from harvest or natural disturbance) or enhancing sequestration. Projects may apply a combination of practices implemented together in the same area.

VM0047 Afforestation, Reforestation, and Revegetation, v1.0, Active on September 28, 2023, https://verra.org/methodologies/vm0047-afforestation-reforestation-and-revegetation-v1-0/

> This methodology quantifies carbon removals from activities that increase the density of trees or other types of woody vegetation. It provides two approaches for quantifying such carbon removals from afforestation, reforestation, and revegetation (ARR) activities.
>
> Area-based approach: This approach combines plot-based sampling, remote sensing, and a dynamic performance benchmark to test additionality and establishes the crediting baselines at every verification.
> Census-based approach: This approach applies to smaller projects where a full census of plantings is feasible. This approach best suits dispersed planting activities (e.g., urban forestry, agroforestry, shelterbelts, and revegetation activities that do not meet the forest definition). Under this approach, additionality is demonstrated with a project method and

the crediting baseline is set to zero if conservative criteria are met. *VMD0054 Module for Estimating Leakage from ARR* Activities must be applied in conjunction with this methodology to account for leakage related to the displacement of pre-project agricultural activities caused by the baseline agent or other actors.

VMD0054 Module for Estimating Leakage from ARR Activities, Sept 2023, https://verra.org/methodologies/vmd0054-module-for-estimating-leakage-from-arr-activities-v1-0/

> This module must be used with VM0047 Afforestation, Reforestation, and Revegetation (ARR) methodology to estimate activity shifting and market leakage from ARR activities. The module calculates leakage based on the reduction in agricultural commodities or fuelwood produced within the project area, less any leakage mitigation activities enhancing production outside the project area. It provides estimates of net production replaced in the market, the amount of new forest lands cleared for displaced production outside the project area, and the associated carbon stock emissions.

VM0044 Methodology for Biochar Utilization in Soil and Non-Soil Applications, v1.1, https://verra.org/methodologies/vm0044-methodology-for-biochar-utilization-in-soil-and-non-soil-applications/

> This methodology quantifies the carbon dioxide removals resulting from the conversion of waste biomass into biochar at new biochar production facilities. Eligible soil and non-soil applications include crop and grasslands and emerging products such as biochar-amended concrete and building materials. This methodology is applicable globally.
>
> Updated version (v1.1) of VM0044 Methodology for Biochar Utilization in Soil and Non-Soil Applications published July 5, 2023 https://verra.org/verra-publishes-updated-biochar-methodology/ includes several minor corrections as well as clarifications of methodological procedures, pertaining to the following topics:
> - Eligible feedstocks and eligible land types for soil application (Section 4)
> - Greenhouse gas (GHG) sources included in the project boundary (Table 2)
> - Equations for quantifying GHG emissions and removals (Section 8)
> - Parameters needed for validation (Section 9)
> - Procedures for reassessing the standardized activity method (Appendix 1)
> - Procedures for demonstrating that feedstocks are waste biomass (Appendix 2)
>
> Any feedback received will be considered for inclusion in VM0044 Methodology for Biochar Utilization in Soil and Non-Soil Applications, v2.0. Verra expects to begin the revision process later this year with the anticipated publication of v2.0 in 2024.

AM0057 Avoided Emissions from Biomass Waste through use as a feedstock in pulp and paper, cardboard, fiberboard, or bio-oil production, opened December 15, 2023, https://verra.org/methodologies/revision-to-am0057-avoided-emissions-from-biomass-wastes-through-use-as-feed-stock-in-pulp-and-paper-cardboard-fiberboard-or-bio-oil-production/

> CDM Methodology AM0057 Avoided emissions from biomass wastes through use as feedstock in pulp and paper, cardboard, fiberboard, or bio-oil production (external link) applies to project activities that involve the construction of new pulp and paper, cardboard, fiberboard, or bio-oil production facilities that use agricultural wastes as feedstock. This

revision to the methodology expands the applicability to wood waste.

VM0003 Methodology for Improved Forest Management through Extension of Rotation Age, v1.3, May 2023, ineligible pending review, https://verra.org/methodologies/vm0003-methodology-for-improved-forest-management-through-extension-of-rotation-age-v1-3/

>This methodology quantifies the GHG emission reductions and removals generated from improving forest management practices to increase the carbon stock on land by extending the rotation age of a forest or patch of forest before harvesting. By extending the age at which trees are cut, projects increase the average carbon stock on the land and remove more emissions from the atmosphere.
>This methodology is applicable to managed forests where clear cutting or patch cutting practices are implemented in the baseline.

VM0010 Methodology for Improved Forest Management: Conversion from Logged to Protected Forest, v1.3, ineligible pending review, https://verra.org/methodologies/vm0010-methodology-for-improved-forest-management-conversion-from-logged-to-protected-forest-v1-3/

>This methodology quantifies the GHG benefits generated from preventing logging of forests that would have been logged in the absence of carbon finance. This methodology is applicable where the baseline scenario includes planned timber harvest, and under the project scenario, forest use is limited to activities that do not result in commercial timber harvest or forest degradation. This methodology is applicable to tropical, temperate or boreal forests. The latest revision of VM0010 includes mechanisms to quantify the emissions resulting from establishing forestry infrastructure (eg, clearing roads, skid trains and log landings), as well as the fossil fuels from forestry machinery including mechanized felling, skidding, forwarding, haling, loading and transporting the wood products inside the project area.

VM0035 Methodology for Improved Forest Management through Reduced Impact Logging, v1.0, under review 2023, https://verra.org/methodologies/vm0035-methodology-for-improved-forest-management-through-reduced-impact-logging-v1-0/

>This methodology is applicable to projects which implement reduced impact logging practices to reduce greenhouse gas (GHG) emissions (RIL-C practices) in one or more of three GHG emission source categories: timber felling, skidding and hauling. RIL-C practices may entail a range of improved logging and harvest planning practices, including, but not limited to: directional felling, improved log bucking, improved harvest planning via pre-harvest inventory, skid trail planning and/or monocable winching, and reduction on width of haul roads and size of log landings.
>
>To ensure credible estimation of emissions reductions, the impact parameters applied by this methodology are quantitative and outcome-based, rather than process-based. The methodology has been designed to ensure that emission reductions achieved based on one impact parameter are not reversed by excessive emissions with respect to another impact parameter. This methodology must be used in conjunction with a region-specific performance method module.

Approved baseline and monitoring methodology AM0057, https://verra.org/wp-content/uploads/2023/12/Avoided-emissions-from-biomass-wastes-through-use-as-feed-stock-in-pulp-and-paper-cardboard-fibreboard-or-bio-oil-production.pdf

The methodology is applicable for project activities using agricultural wastes as feed stock for: pulp and paper, cardboard, fibreboard or bio-oil production, where the end product is similar in characteristics and quality to existing high quality products in the market and does not require special use or disposal methods.   The following conditions apply to the methodology: • The project activity is the construction of a new pulp and paper, cardboard, fibreboard or biooil production facility that uses agricultural wastes as feedstock; • The waste should not be stored in conditions that would lead to anaerobic decomposition and, hence, generation of CH4; • The pulp and paper, cardboard, fibreboard or bio-oil produced with the agricultural wastes is of similar characteristics and quality to existing high quality products in the market and does not require special use or disposal methods; • During the production of pulp and paper, cardboard or fibreboard no significant additional process leading to emissions of greenhouse gas compared to the baseline scenario, except for electricity and fossil fuel consumption, is envisaged (an example of this can be the use of substance produced with highly GHG intensive activities). If this is the case, then the project participant must submit a request for deviation to include emissions from this source; • Emission reductions are only claimed for avoidance of methane emissions when it can be demonstrated that the agricultural residues are left to decompose anaerobically; • In the case of bio-oil, its production does not involve a process that leads to emissions of greenhouse gas except for those arising directly from pyrolysis, or associated with electricity or fossil fuel consumption; • In case the biomass is combusted for the purpose of providing heat or electricity to the plant, the biomass fuel is derived from biomass residues, as specified in ACM0006; • In the case of bio-oil, the pyrolysed residues (char) will be further combusted and the energy derived thereof used in the project activity. The residual waste from this process does not contain more than 1% residual carbon. The on-site energy generation source supplying energy to the production plant can be a CDM project activity. To allow this option, only the amount of agricultural waste used as a feedstock in the project activity shall be considered for the purpose of calculating baseline emissions. For this purpose, the amount of agricultural waste recovered and supplied to the production plant, but used for other purposes such as heat and power production also needs to be monitored.

VT0001 Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities, v3.0, https://verra.org/methodologies/vt0001-tool-for-the-demonstration-and-assessment-of-additionality-in-vcs-agriculture-forestry-and-other-land-use-afolu-project-activities-v3-0/

The tool provides a step-wise approach to demonstrate and assess additionality for AFOLU project activities. New and revised VCS methodologies may reference and required the use of the tool to demonstrate additionality of AFOLU project activities. This tool is adapted from the CDM Tool for the demonstration and assessment of additionality in A/R CDM project activities.

Appendix 4: Ethnographic Futures Research Full Report

The Future of Carbon Sequestration for Washington's Small Forest Landowners

By Dr. Guy Trombley, Ph.D.

Report completed through an agreement between the, WFFA CARBON WORKING GROUP

Date: June 28, 2024

Introduction:

This research aims to support the small forest landowner work group established under Washington's Climate Commitment Act by conducting interviews with small forest landowners (SFLOs). It seeks to identify effective incentives to engage SFLOs in Climate Smart Forestry Practices and Washington's carbon sequestration credit market permanently. Focusing on carbon sequestration in Washington's small privately owned forests, the study explores the willingness and motivations of SFLOs to participate in carbon credit markets under the state's Climate Commitment Act (SB 5126, 2021), which introduces policies and programs to mitigate climate change effects and address carbon emissions.

Employing Ethnographic Futures Research methodology, the study examines motivations, incentives, and disincentives affecting SFLOs' involvement in critical environmental activities. By analyzing SFLOs' demographics, values, land use practices, and challenges such as financial, regulatory, and technical knowledge barriers, this report aims to illuminate the intricate dynamics of forest management and carbon sequestration in Washington State, contributing to the future design and development of effective programs for climate change mitigation.

This research focuses on the future of carbon sequestration in Washington's Small privately owned forest lands and the role of Small Forest Landowners engaging in that process. Its aim is to better understand the willingness and motivations of SFLOs to engage in carbon sequestration credit markets by practicing Climate Smart Forestry Practices. The context of Washington's Climate Commitment Act (SB 5126 (2021) is largely about employing new polices, programs and practice to address the rapidly accelerating problems climate change is having on our planet and how can we best develop mitigate the cumulative past carbon emitting behavior of humanity by planning to implement successfully designed programs for the near future.

To that end the following work is based on a standard Ethnographic Futures Research methodology to delve into the motivations, incentives, as well as considers disincentives that influence SFLOs' participation in these environmentally critical activities. This type of study at its heart, is about the behavioral economics of SFLS. By examining the range of the SFLO population, their values, land use practices, and the challenges they face, including financial constraints, regulatory hurdles, and the need for technical knowledge, this report sheds light on the complex landscape of forest management and carbon sequestration in Washington State.

Purpose:

The purpose of this study is to extract insights and recommendations that will effectively incentivize SFLO to willingly engage in forest management practices that will increase the capacity of their small forest to capture, store and reduce atmospheric carbon to mitigate that rapid increase in the multitude of highly undesirable impacts of climate changes. Given the scale of these challenges, rapidly increasing impacts and growing requests for credible solutions to climate change, the global human ecological significance cannot be overstated here. Therefore, the SFLO Carbon Working Group leadership is seeking data collection, analysis, and information on the various critical factors (the incentives and disincentives) influencing the largest number of future participants must overcome to enthusiastically participate for a carbon sequestration pilot program to be successful and scale rapidly.

Context

The setting of the research is framed by the State of Washington Department of Natural Resources Upland Map below. For the purpose of this study, the 6 sectors outlined in Map A. Red to organize the regional selection criteria for interview informants. The Map B below shows the locations of each SFLOs selected as informants from across the state.

Map A

Population

The population of SMALL FOREST LANDOWNERS in the 2020 survey is over 218,000 represents a rather heterogeneous population. The known demographics of this population are limited to the following generalizations.

- Age- Averages around retirement or later age
- Race- Predominantly White
- Socioeconomic State- Middle to upper middle Income

Characteristics

- Somewhere between 25,000 and 50,000 small forest landowners are likely anticipating selling all or some of their forest land in the coming 10 years. Somewhat fewer than 1 in 10 current SFLOs have likely ever sold or given away some, but not all, of their forest land.
- The most important aspects of ownership for SFLOs, on average, are beauty and scenery, provision of wildlife habitat and environmental benefits, and privacy and personal attachment. "The protection of water resources" ranks highly as an ownership objective among Washington State SFLOs.
- SFLOs types of land use ranges
  - small minority who has a sole focus on income and investment from their forests, but they tend to own disproportionately more of the state's Small Forest Land.
  - the majority of SFLOs tend to value their forest lands primarily for Family and Privacy purposes but tend to own a small amount of Small Forest Land. Many of these SFLOs give low priority to timber harvesting yet still practice some forest management.

Trends Impacting Population

Trends impacting Small Forest Land Ownership (page 12 of 88 in Legislative Report Draft)

SFLO Changes in Uses of Forest Land

Washington State's forest area decreased by 2%, from 19.64 million acres in 2007 to 19.25 million acres in 2019.

Small forest landowners (SFLO) experienced a 3.7% decline in forest acres, from 2.99 million in 2007 to 2.88 million in 2019, and a 4% reduction in total parcel acreage, from 5.04 million to 4.84 million acres, despite an 8.5% increase in their number from 201,000 to 218,000.

In 2007, 77% of SFLO owned less than 20 acres, contributing to 22% of forest acres, while the majority of SFLO forestland was held by owners with 100 to 1000 acres (36%), followed by those owning 20 to 100 acres (30%).

SFLO forest acres in the smallest size classes (<20 acres, 20-100 acres, 100-1000 acres) decreased by 117,000 acres between 2007 and 2019, whereas acres in the largest classes (1000-5000 acres, 5000+ acres) grew by 13,500 acres.

The number of SFLO increased across all size classes, with the most significant growth of 9,700 owners in the 20-100 acres category.

From 2007 to 2019, SFLO forest acres in forestry or natural land uses decreased by 5.7% (121,500 acres), while residential use acres increased by 9% (48,600 acres).

Approximately 450,000 acres (15%) transitioned out of SFLO, and 238,000 acres (8% of the 2007 area) transitioned into SFLO between 2007 and 2019.

Of the acres leaving SFLO, 67% remained forested, with Private Industry (107,000 acres) being the largest recipient, followed by Private Other (60,000 acres), Tribal (50,000 acres), and Private Conservation (25,000 acres).

The largest share of acres transitioning into SFLO in 2007 came from Private Industry, totaling 92,000 acres

Methodology

Description of Ethnographic Futures Research

Ethnographic Futures Research (EFR) is a specialized form of ethnography designed to explore the perceptions of a culture's future. This method employs mixed methods, data collection techniques, and societal trend analysis. A common approach involves detailed interviews where participants describe two or three potential scenarios: optimistic, pessimistic, and most probable, within a reasonable future timeframe of about 20 years.

Scenario Construction

Each interviewee contributes by constructing scenarios that address:

- Possible desirable or probable undesirable futures for the target population.
- The level of knowledge or uncertainty surrounding these futures.
- Implications and potential consequences.
- Early warning signs of undesirable outcomes.
- Understanding underlying processes, motives, and incentives for change.

Understanding Scenarios

A scenario within EFR is essentially a narrative outlining an imagined future, offering insights into potential outcomes at a specified horizon date. These scenarios are descriptive narratives that help in understanding various perspectives and possibilities regarding the future of a particular population with some shared interests. Most importantly these scenarios reveal the underlying perceptions, assumptions, motivations derived from present life experience extrapolated into the future. The full descriptive narratives will be included at the end of this report.

Application of Research Findings

The utility of these future scenarios, built upon the analysis of the interview data from the perspectives of small forest landowners, is to help inform decision makers with reliable descriptions of what a common desirable and undesirable future would look like. Then using the resulting insights to design well aligned policies, programs, and practices that help create a desirable realistic future and prevent the undesirable probable future from occurring: A future outcome that will effectively incentivize SFLOs to engage enthusiastically in participating in forest management practices that will increase the capacity of their small forest to capture, store and reduce atmospheric carbon that is leading to an rapid increase in the multitude of highly undesirable impacts of climate changes.

Application: Small Forest Landowner Carbon Workgroup

In the context of the Small Forest Landowner Carbon Workgroup, EFR focuses on envisaging the future of small forest landowners, particularly exploring the incentives necessary for their engagement in carbon sequestration programs.

Value of Diverse Perspectives

While EFR may initially target leaders or experts in the field, incorporating diverse perspectives of a range of perspectives proves invaluable, especially when experts, policy makers, planners, program designers encounter challenges trying to develop strategic approaches and solutions beyond their present understanding.

Participant Selection

Typically, EFR involves a diverse group of participants, often numbering thirteen or more, to ensure an acceptable range of perspectives on the research theme. This research specifically included 23 informants given its budget parameters.

Data Analysis

EFR employs constant comparative analysis to identify patterns in interviewee data, revealing underlying similarities and differences in human behavior. This analysis integrates existing research, population projections, land use trends, and policy implications to recommend programmatic actions.

Behavioral Economics Perspective

The range of SFLO perspectives, from enthusiastic supporters to resistant individuals, is explored within the framework of behavioral economics, considering the economic and cultural context of future forest farm systems.[2]

Findings and Recommendations

Understanding Driving Forces

Descriptions of the forces driving behavior, including opinions, attitudes, biases, values, beliefs, and motivations, offer insights into potential disincentives like barriers to participation as well as incentives like technical and labor assistance of financial renumeration for their engagement. The study uncovers

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[2] "Principles of Behavioral Economics" by Peter E. Earl, published in 2022.

multiple attributes of Carbon Smart Forest Management and practices as well as financial incentives of carbon sequestration credit markets and their associated incentives. This work will highlight the nuances and complexities of motivating participation and engagement in these programs and possibilities.

The research provides recommendations for overcoming barriers and resistance to participation in carbon sequestration programs, aiming to facilitate the adoption of forest practices that enhance carbon storage and sequestration.

Ethnographic Futures Research offers a valuable framework for exploring and understanding the complexities of future scenarios, providing insights that can inform policy, program design, practices, and decision-making processes in various domains. When the findings from EFR are analyzed in conjunction with other research, particularly trends analysis can help further corroborate and align the final recommendations and design.

Objective of the Ethnographic Futures Research Initiative

To conduct research that elicits from Washington State Small Forest Landowners (SFLOs) patterns, themes, insights and actionable recommendations on the types of incentives and disincentives that will effectively engage them in the State's future Carbon Sequestration Credit Market.

The goals of Washington's Small Forest Landowner (SFLO) WFFA CARBON WORKING GROUP

EFR Initiative is to produce the necessary and actionable research insights to help inform and frame the
1. decision making, policy advocacy, grant funding, program development process
2. design of an adaptable and durable Carbon Sequestration Pilot Program
3. next steps of research and design needed to evaluate, refine, and scale up the pilot to a statewide model program that perhaps benefit other states in similar efforts.

The target audience for this research is legislative leaders who are interested in creating a future carbon sequestration credit market and subsequent programs they will successfully engage small forest landowners in perpetuity. A program targeted at sequestering human produced climate changing greenhouses gases like CO_2 in the forms of forest growth.

Outline of the Ethnographic Futures Research approach used, highlighting its appropriateness for the study.
- The Futures Research initiative is an inductive iterative process which continuously refines the results and products of the work.
- The following methodology is designed to reach the closest approximation of the research goals the budget can afford.

In a good faith effort of using social science's inductive approach,
- Description of data collection methods (e.g., Interviews, Document Analysis, Event Analysis).

The primary data collection method is a long form interview style lasting 60 to 90 minutes in length. Grand tour type questions frame the responses of the informants. Of the 23 people interviewed, 22 interviews ranged from 120 to 180 minutes in length, only 1 interview was 90 minutes in length. The sum of over 50 hours of oral interviews rendered 1000s of pages of transcriptions provides that data collected

for the analysis presented in this Technical Research Report.

Sample of SFLOs

Characteristics of the Study Participants

Sample Population Selection Criteria- Great pains were taken to develop a selection criterion that attempted to get a representative sample from the population. Spending days analyzing over 600 SFLOs field notes taken by Washington State DNR's site visit records of SFLOs. While the 23 informants selected represented a diverse sample geographically, from all corners of the state with trees, as well as variance in scale from 1800 acres to 5 acres, special attention was paid to sorting and identifying SFLOs with a balance of the following characteristics.

- Demographics
  - Age
  - Sex
  - Race/Ethnicity
  - Occupation
  - Forestry Experience, Education, Training
  - Succession Planning
- 6 Geographic Regions of the State
- Scale of Property in Acres
- Land Use-ranges from farm forestry to Forest Management practices that also emphasized forest health, resilience, wildlife habitat
- Legacy Small Forest Lands that have been in families for as many as five generations to new SFLOs.
- Environmental Conditions- events like forests heavily impacted by wildfires, disease, drought, changes in climate, and
- Human Impact from accelerating land development patterns

When all is said and done the sample taken from the population of 218,000 Small Forest Landowners representative range of properties from all regions of the state, different forest types, scales of acreage, duration of ownership, land use types, environmental conditions, human impact. Yet, it needs to be clearly noted that the demographic characteristics in this sample remained fairly homogeneous, except for range of forestry experience as well as sex as there was a near equal number of males to females. Thus, the sample of informants from the population I had access to entirely lacked traditionally underrepresented populations from race and ethnicity, lower socioeconomic status, age, disability.
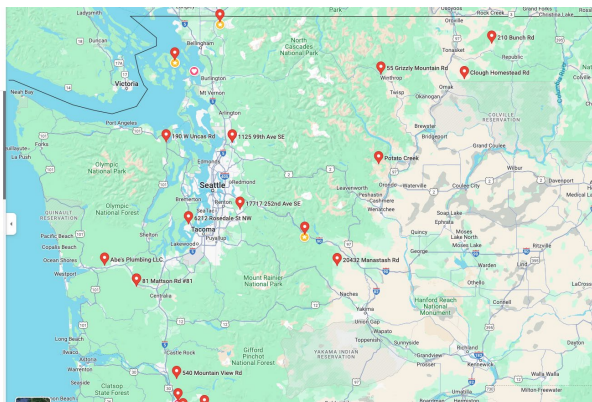
Analysis-

Using a constant comparative method of iterative analysis the transcriptions were analyzed for sentiment, patterns and themes. As each interview was completed and cross analyzed with each of the other interviews, patterns emerged, and themes solidified. As the data analysis show repeated patterns of similarities and differences the results achieved a degree of analytical saturation,[3] adding a degree of confidence that the study effectively captured the range of a rather heterogeneous sample of Small Forest Landowners Perspectives. The following methodology is designed to reach the closest approximation of that goal the budget can afford. In a good faith effort of using social science's inductive approach, it is the researcher's responsibility to provide constant updates on reaching this goal within the parameters of the budget. However, as previously discussed with the Carbon Working Group's leadership, there may be a need for additional resources to reach a degree of confidence of results that are aligned with the goals of this study and recommended by the Working Group's leadership.

Findings: Ethnographic Futures Research

Based on the above findings of the Ethnographic Futures Research, trends research, climate projections and a selection of the recommendations made by informants. These composite pictures are in the form of the two following short narratives which are reported in this document in the following two forms, 1.) typical research reporting summarizing the patterns, themes, impacts of trends that are then used to generate specific research informed recommendations, 2.) Uses these findings to develop two composite narrative sketches (scenarios) of a desirable possible future and an undesirable probable future if the policies, programs, and practices recommended to some varying degree succeed or fail to incentivize the desired engagement of Small Forest Landowners in Washington State's proposed Carbon Sequestration Market Program. These two scenarios can be useful to decision makers to help see what
1. a desirable possible future could and might look like if the recommendation human interventions are, to some varying degree successful.

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[3] "Saturation has attained widespread acceptance as a methodological principle in qualitative research. It is commonly taken to indicate that, based on the data that have been collected or analyzed hitherto, further data collection and/or analysis are unnecessary." Saunders B, Sim J, Kingstone T, Baker S, Waterfield J, Bartlam B, Burroughs H, Jinks C. Saturation in qualitative research: exploring its conceptualization and operationalization. Qual Quant. 2018;52(4):1893-1907. doi: 10.1007/s11135-017-0574-8. Epub 2017 Sep 14. PMID: 29937585; PMCID: PMC5993836.

2. an undesirable probable future could and might look like if the recommendation human interventions are, to some varying degree unsuccessful in their implementation, for if they not implemented at all.

These Two Scenarios are included just before the conclusion to provoke a period of reflection on what future, from the eyes of Small Forest Landowners might very well look like and to engage you own perspective on what the possible or probably consequences path you as decision makers choose to take in establishing a Climate Smart Forestry Management Program and a related Carbon Market for Small Forest Landowners.

Patterns and Themes

In qualitative research, the analytical relationship between patterns and themes is foundational to interpreting the data. Patterns in qualitative research refer to recurring elements or common or shared regularities observed within the data, which can include behaviors, experiences, ideas, perceptions, values, opinions, or phenomena. Themes, on the other hand, represent broader insights or concepts that emerge from these patterns, providing a deeper understanding of the data's underlying meaning.

Summary of significant patterns and key themes identified through the interview research.

#1 Patterns: Common Financial Challenges, Constraints and Concerns

The first set of critical patterns impacting Small Forest Landowners (SFLOs), centers around financial challenges, constraints, and concerns associated with adopting Climate Smart Forestry Practices. These patterns are then summarized into a cohesive theme below that underscores the economic and logistical hurdles SFLOs face in contributing to forest health and resilience while attempting to derive financial benefits from their lands. The narrative theme is shaped by three interconnected patterns (1 Financial Constraints, 2.) Small ROI, 3.) Large Upfront Investment Costs. The following patterns are represented in rank order, meaning from the most frequently commented on to the least frequently commented on in the interviews.

Financial Constraints

All the informants in the sample remarked on the **high cost of the management of Small Forest Land** ownership. As each interviewee imagined engaging in the Climate Smart Forestry Practices that would help optimize or at least increase forest health and resilience, yet the topic of the high upfront financial costs became the leading focus of their responses. Whether the properties were as small as 20 acres or as large as 1400 acres, SFLOs, even with limited technical knowledge of the Climate Smart Forestry Practices, have a rough estimate of how much work needs to be done to have a positive and much desired impact on forest health and resilience. The perception of high upfront costs, maintenance, and implementation of sustainable forest management practices that would legitimately qualify for engagement in the benefits of the Carbon Credit Market appear to be a significant and potential barrier to overcome designing a successful implementation of just such a program.

Small ROI

There are a range of challenges that negatively impact the ability of SFLOs to convert some of their forest resources into needed income to support their family financial requirements as they age, but also to increase the quality and quantity of their small forest land management. Numerous interviewees commented on **the rising costs of labor, equipment, transportation as well as the increasing distance for many remote SFLO to get their harvest to a mill, and additional need for technical assistance all function to reduce or limit potential ROI for landowners who would otherwise consider getting some returns from forest products.** Without additional resources for properly caring for their forest, it would be difficult to properly incentivize SFLO to participate in the level of forest management necessary for Certified Forest Management Plans. The following are a few of the most commented on limitations.

The smaller the scale of the forest lands the lower the ROI value is for SFLOs to be financially incentivized, motivate, participation in Climate Smart Forestry Practices. Providing incentives for different scales of forest land that will incentivize all SFLOs to "doing the right thing" to play their part in ecological restoration and mitigation of climate change will require additional investigation.

Large upfront Investment Costs

For many SFLOs the **initial investment appears to be large and the return on that investment over the long-term is perceived to be small.** This constraint, if not overcome by well-informed policies, programs and practices, will act as a significant disincentive as well as has different problematic dimensions. Based on the size and type of forest and the condition it is in, the upfront cost would vary greatly. New SFLOs report the costs to reestablish some degree of forest health and resilience is a challenge since any number of small forest lands can and are often managed by benign neglect. Whether it is because an owner may be passing the age where sweat equity is progressively decreasing, the ROI is low enough not to motivate any further investment, or the options for a succession plan are so few or highly uncertain it is hard for SFLOs to figure out how to prioritize and budget for routine forest management. Even with support provided from already existing government assistance programs the costs and time required to catch up from neglected forest management practices are imagined to be considerable and vexing.

Theme: Financial and Practical Challenges Implementing Climate Smart Forestry Practices

The theme that encapsulates these above patterns is "Financial and Practical Challenges in Implementing Climate Smart Forestry Practices by Small Forest Landowners (SFLOs)." The central narrative revolves around the significant financial barriers and limited returns on investment (ROI) that SFLOs face when attempting to adopt sustainable forest management and climate smart practices. Despite recognizing the importance and benefits of enhancing forest health and resilience, SFLOs are daunted and perhaps deterred by the perception of high upfront costs, ongoing maintenance expenses, and the small financial returns (ROI) over the long term.

These challenges are compounded by practical difficulties such as rising costs of labor, equipment, and transportation, especially for remote locations, alongside an increased need for technical assistance. The relative scale of the property further influences the financial viability and salience of incentives for adopting these practices, with smaller lands yielding lower ROI and thus relying more on ecological and climate change mitigation motivations than financial ones. The excerpt highlights a complex interplay of economic, logistical, and motivational factors that hinder the engagement of SFLOs in climate smart forestry, pointing towards a need for well-informed policies, programs, and assistance to overcome these barriers and enable effective and sustainable forest management.

Trends

Given the set of patterns that make up the theme, **Financial and Practical Challenges in Implementing Climate Smart Forestry Practices by Small Forest Landowners**, the following trends further compound the complexity of this set of financial factors and add further insights needed for data uniformed recommendations.

- Small Forest Landowners average age is near or equal to that of retirement age, meaning this is a period of life where people are living on or planning to live on a fixed income for their remaining years, decreasing their ability to be able to afford more costly aspects of forest management.

- Small Forest Owners that are progressively aging out of the heavier labor aspects of forest management, reducing their ability to invest greater amounts of sweat equity and increasing their need to afford more costly aspects of forest management.

- Small Forest Landowners report difficulties in securing an adequate succession plan or existing plan due to a lack of heirs, and to varying degrees concerns about Land Trusts not honoring their lifelong care and aligning with their vision for their Small Forest Lands future.

- Small Forest Landowners in this aging demographic, "...between 25,000-50,000 small forest landowners are likely anticipating selling all or some of their forestland in the coming 10 years. Somewhat fewer than 1 in 10 current SFLOs have likely ever sold or given away some, but not all of their forest land." (Page 13 WFFA Jan 4th Working DRAFT).

Increase in sales of Small Forest Land plays into the trend of further subdividing larger partials of forest land, the larger the partials the more advantageous for the efficient administration and management of CSFP and CCM. Recommendation: Design some equitable policy and program that incentivizes the aggregation of small forest lands back into larger partials.
Each of these documented trends further intensify the need for following the recommendations to effectively address, "Solve for," the above Financial and Practical Challenges in Implementing Climate Smart Forestry Practices to properly incentivized SFLOs to enthusiastically engage and realize the benefits of the Carbon Sequestration Credit Market programs. Another way to say this by addressing these challenges the program would remove the disincentives to participation.

Taxation and Insurance Issues: Burden of taxes and inadequate insurance coverage were a persistent conversation for SFLOs. Although, all the informants were genuinely grateful for the range of support programs that already help like Designated Forest Land. However, the formal published stipulation "The land must be used primarily for growing and harvesting timber" creates several situations in which a SFLO is confronted with two or more irreconcilable demands or a perceived forced choice between multiple undesirable courses of action. This perception of the stipulations of Designative Forest Land, misinformed or not, creates a classic double bind in the minds and comments of those SFLOs who particularly

1. do not wish to harvest timber are inclined to engage in a new Carbon Sequestration Credit market see a contradiction in this special tax benefit that requires them to harvest trees.
2. in that the counties themselves may never see any financial benefit from this special tax designation. And one wizened SFLO suggested this program is not fair for either some the SFLOs or the Counties in need of the outstanding tax revenue.
3. For SFLOs inclined to harvest trees, particularly in Eastern and remote parts of Washington, where mills and markets are far and few between, the increase in transportation cost further reduces the ROI.

Recommendations

Policy Recommendations:

Create a new Tax designation for SFLOs who are engaging in the Carbon Sequestration Credit Market, or some hybrid version that allows for some exchange of benefit for pre-commercial thinning and later harvesting within the terms of the Carbon Sequestration protocols.

Insurance Issues also place an additional burden on SFLOs, as the cost per acre will likely increase as the impact of climate change accelerates the conditions and consequences for fire, flood and landslide potential. For some interviewees, they were not aware of the financial assistance initiative by Washington State's Department of Natural Resources (DNR), previously known as the cost-share program, which is dedicated to enhancing wildfire resilience and forest health. It offers both technical and monetary aid to landowners for carrying out treatments related to forest health and wildfire prevention, as well as for the creation of forest management plans.

Program Recommendation:

Increase the public awareness and education campaigns for SFLOs to help defray the rising costs of insurance, particularly related to wildfires. One SFLO in Northeastern Washington lost his entire home, outbuildings and property because he was unable to insure his property nor was, he aware of the cost sharing program with the DNR, and the fire spread from National Forest Land to his land.

#2 Patterns: Common Policy and Regulatory Concerns

The analysis of the Small Forest Landowners (SFLOs) concerns about adopting Climate Smart Forestry Policies and Regulations reveals a complex landscape of financial, regulatory, and logistical hurdles.

These challenges, derived from interviews, are prioritized into three main patterns: 1. Certification and Compliance, 2.) Policy Uncertainty, and 3.) Permitting Process.

Certification and Compliance

The most significant concern is the anticipated difficulty in complying with the standards necessary for carbon credits. This issue reflects broader anxieties around the feasibility of meeting complex certification requirements, which can be particularly daunting for SFLOs lacking the resources and expertise to navigate these processes. The emphasis on this challenge highlights a critical gap between the objectives of Climate Smart Forestry Policies and the practical capabilities of small landowners.

Policy Uncertainty

SFLOs express a deep sense of uncertainty stemming from their experiences with the volatility of policies, the ambiguity of guidelines, and the constraints imposed by zoning and land-use restrictions. This uncertainty is aggravated by a perceived lack of continuity in policy frameworks over time, suggesting a need for more stable and transparent policy environments to build trust and encourage long-term planning among SFLOs.

Application Processes for Entry to Programs

The complexity and time-consuming aspect of the application process, filing the paperwork, dealing with bureaucratic red tape and the like are identified as significant barriers, particularly for those without the professional experience or resources to effectively navigate these requirements. This negative impact on willing SFLOs is magnified by the large number of helpful programs available, often all having very different approaches to applications and requirements. Such impacted patterns indicate a broader issue within the regulatory framework, red tape and that disproportionately affects less experienced and/or smaller-scale forest landowners. The effect is to reduce their incentive to access to programs intended to support sustainable forest management.

Theme: Challenges navigating bureaucratic and frequently changing regulations

The second most frequently referenced theme in the challenge category is the difficulty in navigating bureaucratic and frequently changing regulations emerging as a critical theme for Small Forest Landowners. This challenge is not limited to the inexperienced; even those with significant experience and larger land holdings find the regulatory landscape particularly daunting. All but the most experienced and professional SFLOs of larger properties remarked on the importance of overcoming the technical and bureaucratic barriers to accessing programs beneficial to management for a healthy, diverse and resilient forest ecosystem. The need for simplification and clarification of regulations is emphasized, particularly for those engaged in timber harvesting. Simplifying access to management programs could serve as a powerful incentive for increased SFLO participation, promoting a more inclusive approach to achieving forest health, diversity, and resilience.

Trends

Given the above set of patterns that make up this theme of the challenges navigating bureaucratic and frequently changing regulations by Small Forest Landowners, the following trends further compound the complexity of this set of financial factors and add further insights needed for data uniformed recommendations.
Task: Identify Present Trends in changing Bureaucratic and Regulatory systems in Washington State.

Model Examples:
Federal- Red Tape Reduction Act Summary: S.1725 — 118th Congress (2023-2024) Bill Sponsor Senator Wyden OR

Each of these documented trends further intensify the need for following the recommendations to effectively address, "Solve for," the above Financial and Practical Challenges in Implementing Climate Smart Forestry Practices to properly incentivize SFLOs to enthusiastically engage and realize the benefits of the Carbon Sequestration Credit Market programs. Another way to say this by addressing these challenges the program would remove the disincentives to participation.

Recommendations

To address these challenges, several policy and regulatory recommendations emerge:

Policy Recommendations

- Engage SFLOs in Policy Development: Involve SFLO representatives in the development and review of forestry policies and regulations to ensure that new initiatives are practical, equitable, aligned and supportive of SFLO needs and capabilities.

- Stabilize Policy Frameworks: Develop clear, consistent policy guidelines that provide long-term stability and predictability for SFLOs, encouraging/incentivizing investment in sustainable practices.

Program Recommendations

- Simplify Certification Processes: Streamline certification requirements for carbon credits and other sustainability incentives to make them more accessible to SFLOs of all sizes and experience levels. (see below)

- Streamline Permitting Processes: Create a permitting process to reduce complexity and processing times, potentially through the introduction of digital platforms that simplifies and integrates the site assessment, development plan, application and ongoing tracking/evaluation processes. This also needs to be transferable to new owners or land trusts.

- Enhance Support and Education: Provide targeted technical support and continuing education programs for SFLOs to navigate regulatory and policy landscapes, including technical assistance, financial grants, and training programs. Additionally, keeping SFLOs informed on the progress and regress of their Climate Smart Forestry Practices to sustain the human motivation gained the positive improvements and rewards that come from attaining steps to the larger goals for their forests and Climate Change Mitigation.

Practice Recommendation

- **Small Forest Land Navigators-** Develop a larger workforce of professional Small Forest Land Navigators equipped with the technology and tools necessary to make rapid assessments of each property and customize a Climate Smart Forestry Plan that qualifies for participation in the Carbon Sequestration Credit Market Benefits.
- **Navigation Technology Innovation-** Design and develop an application-based tool for Navigators to do a rapid and thorough assessment of privately owned small forest lands that produces a certified Climate Smart Forest Manage plan customized to the unique

attributes of each SFLOs property. This plan would initially qualify a SFLOs for participation in the Statewide Small Forest Landowner Carbon Sequestration Credit Market. It would also provide the basis for continued performance evaluations that world track the improvements and degree of involvement SFLOs are engaged in. As one interviewee put it, "this program should not benefit people for doing nothing."

Addressing these recommendations could significantly alleviate the challenges that disincentivize SFLOs, thereby incentivizing a more inclusive and effective approach to implementing Climate Smart Forestry Policies and contributing to broader environmental and climate mitigation goals.

#3 Patterns: SFLO Technical Knowledge and Resources

The third set of patterns impacting Small Forest Landowners (SFLOs) in the context of adopting Climate Smart Forestry Policies and Regulations revolves around the significant technical knowledge and resource gaps. These challenges, derived from interviews, are categorized into three interconnected issues: Lack of Expertise, Information and Support Access, and Educational Support. Each of these patterns underscores the critical need for enhanced knowledge dissemination, resource allocation, and educational initiatives to empower SFLOs in their sustainable forest management efforts.

Lack of Expertise
The majority of SFLOs report limited technical knowledge necessary for effective forest management and carbon sequestration. This issue is compounded by the fact that even among those with some level of expertise, the resources required to implement their knowledge are often inaccessible, prohibitively expensive, or unevenly distributed across regions. This highlights a fundamental barrier to adopting sustainable practices and leveraging forestry for carbon credits, emphasizing the need for more accessible technical resources and financial support.

Information and Support Access
SFLOs frequently encounter difficulties in accessing consistent up-to-date research, best practices, and technological advancements. While information is available, inconsistencies across different agencies create confusion and inefficiencies. Positive experiences with support services indicate a strong foundation upon which to build; however, there remains a pronounced need for additional technical support to address the gaps. This suggests a demand for more cohesive and comprehensive information dissemination mechanisms that can provide SFLOs with reliable and uniform guidance.

Educational Support
There is a clear need for more educational resources and programs tailored to the needs of SFLOs. This encompasses a wide range of potential initiatives, from workshops and online courses to field demonstrations and mentoring programs. The goal of these educational efforts would be to enhance SFLOs' understanding of sustainable forest management practices, carbon sequestration techniques, and the regulatory landscape, thereby equipping them with the knowledge to navigate the complexities of Climate Smart Forestry Policies and Regulations.

The patterns identified within the realm of technical knowledge and resource gaps present a significant barrier to Small Forest Landowners (SFLOs) in effectively adopting and implementing Climate Smart Forestry Policies and Regulations. These interconnected challenges—spanning Lack of Expertise, Information and Support Access, and Educational Support—highlight a critical need for comprehensive strategies aimed at bridging these divides. Addressing these issues is pivotal for enabling SFLOs to contribute more effectively to forest health and resilience, carbon sequestration efforts, and ultimately, to

the broader goals of environmental sustainability and climate change mitigation.

The lack of technical knowledge among SFLOs, coupled with the difficulty in accessing necessary resources and up-to-date information, underscores a broader issue of inequity in the forestry sector. While some SFLOs have made strides in overcoming these hurdles, the majority still face significant obstacles in implementing sustainable forestry practices. This is further complicated by the need for more educational resources and programs tailored to SFLOs, which would equip them with the knowledge and skills required to navigate the complexities of forestry management within a changing environmental landscape.

Theme: Bridging the Gap via Enhanced Technical and Educational Support

The interconnected patterns of Lack of Expertise, Information and Support Access, and Educational Support collectively articulate a significant theme: the pressing need for enhanced technical support and educational opportunities for Small Forest Landowners (SFLOs). This theme underscores the challenges SFLOs face due to limited technical knowledge and resources necessary for effective forest management and carbon sequestration. Despite a genuine interest and willingness among SFLOs to engage in sustainable practices, the gaps in expertise, consistent information access, and educational support significantly hinder their ability to contribute effectively to Climate Smart Forestry Policies and Regulations.

The lack of expertise is a primary barrier, with many SFLOs finding it difficult to access the resources or afford the necessary tools to apply their knowledge practically. This challenge is further exacerbated by the inconsistent and sometimes confusing information provided by various agencies, making it hard for SFLOs to stay informed about current research, best practices, and technological advancements. This statement specifically refers to the variations, differences and sometimes consistencies in federal, state, and local policies or program requirements which recognizes the general confusion that SFLOs can feel when facing the process of engaging in new programs. Moreover, there is a pronounced demand for more comprehensive educational programs that can equip SFLOs with the knowledge and skills needed to navigate the complex landscape of sustainable forest management and policy compliance.

The synthesis of these patterns into a cohesive theme highlights the critical need for a concerted effort to bridge these gaps. By focusing on the development of technical assistance programs, enhancing information dissemination, expanding educational opportunities, facilitating resource sharing, and advocating for financial support mechanisms, stakeholders can empower SFLOs to overcome these hurdles. Such initiatives would not only enable SFLOs to manage their lands more effectively and sustainably but also contribute to broader environmental goals, including climate mitigation and forest ecosystem resilience.

To address these challenges, a multi-faceted approach is recommended. This includes the development of technical assistance programs, the enhancement of information dissemination mechanisms, the expansion of educational opportunities, the facilitation of resource sharing among SFLOs, and the advocacy for financial support mechanisms. Such strategies are crucial for not only empowering SFLOs but also for ensuring the resilience of forest ecosystems and their capacity to contribute to climate change mitigation goals.

Trends

Recommendations

To close these technical knowledge and resource gaps, several strategies could be implemented:

Program Recommendations

- Develop Technical Assistance Programs: Establish or expand technical assistance programs that provide SFLOs with access to expertise in forest management, carbon sequestration, and regulatory compliance. These programs could include consulting services, expert-led workshops, and on-site evaluations.

- Enhance Information Dissemination: Create centralized information platforms that offer consistent, up-to-date research, best practices, and technological advancements relevant to SFLOs. This could involve the development of online portals, regular newsletters, or collaborative networks involving multiple agencies. These platforms should be integrated into the Navigator Tools in previous recommendations to streamline and aggerate the benefits into one report that demonstrates the range of incentives all in one report.

- Expand Educational Opportunities: Increase the availability of educational resources and programs specifically designed for SFLOs. This could include online courses, field days, demonstration projects, and regional conferences focused on sustainable forest management and carbon sequestration.

- Facilitate Resource Sharing: Develop mechanisms for resource sharing among SFLOs, such as equipment leasing programs, cooperative purchasing agreements, or community-based management initiatives, to reduce the financial burden of accessing necessary tools and technologies.

- Advocate for Financial Support Mechanisms: Work with governmental and non-governmental organizations to establish grants, subsidies, or incentive programs that lower the cost barrier for SFLOs seeking to implement sustainable practices and technologies.

Implementing these recommendations requires a concerted effort from governmental bodies, non-governmental organizations, forestry experts, and the SFLOs themselves. By fostering a collaborative and supportive environment, it is possible to overcome the barriers posed by technical knowledge and resource gaps, leading to a more inclusive and effective approach to sustainable forest management. Addressing these patterns through targeted recommendations would not only empower SFLOs with the necessary knowledge and resources to manage their forests sustainably but also enhance their contribution to climate mitigation efforts and the overall resilience of forest ecosystems.

4. Patterns: Environmental and Ecological Concerns

In the comprehensive examination of the challenges confronting Small Forest Landowners (SFLOs) amidst the evolving landscape of Climate Smart Forestry Policies and Regulations, a critical dimension emerges from the interplay of environmental and ecological concerns. These concerns, delineated through patterns of Climate Change Impacts, Increasing Risk of Natural Disasters, and the nuanced balance between Biodiversity and Ecosystem health, collectively underscore the multifaceted nature of sustainable forest management in the face of global environmental changes. This section of the report delves into these interconnected patterns, providing a narrative that contextualizes the environmental and

ecological challenges within the broader objectives of forest resilience, carbon sequestration, and biodiversity conservation.

Climate Change Impacts

The first pattern highlights the pervasive effects of changing weather patterns on forest health, marking a significant concern for SFLOs. The dynamic nature of climate change introduces a complex set of conditions like floods, ice storms, drought and high winds that aggravate the prevalence and severity of wildfires, pests, diseases, as well as the spread of invasive species. These conditions not only threaten the ecological integrity of forest ecosystems but also compromise the emotional vulnerability, economic viability and sustainability of forest land management practices. The exacerbation of these issues by climate change necessitates a reevaluation of traditional forest management strategies, urging SFLOs to adapt to a rapidly changing environmental context. Small Forest Landowners are aware that the increasing speed and intensity of climate impacts on these conditions, requires mitigation: a role many SFLOs are motivated and willing to engage their small forest lands in the solution.

Increasing Risk of Natural Disasters

The Interrelated impacts of climate change is the escalating vulnerability of SFLOs to natural disasters, particularly the increased frequency and scale of wildfires, pests, and diseases. This pattern reflects a growing recognition of the heightened risk landscape that SFLOs navigate, where larger-scale environmental events become more common and more devastating. The susceptibility of small forest lands to these events underscores the urgent need for enhanced risk management and disaster preparedness strategies that can safeguard both the land and the livelihoods dependent on it.

Biodiversity and Ecosystem Balance

At the intersection of climate mitigation efforts and forest management lies the critical issue of maintaining biodiversity while focusing on carbon sequestration. This pattern encapsulates the complexity of balancing carbon sequestration practices with the imperative to preserve biodiversity and ensure ecosystem balance. The challenge here is twofold: on one hand, SFLOs are tasked with optimizing their land for carbon capture as a contribution to climate change mitigation; on the other hand, they must navigate the potential impacts of these practices on biodiversity and the overall health of the ecosystem. This dilemma poses pressing questions about the design and implementation of carbon sequestration practices that are both effective and ecologically sustainable.

A Path Forward

The synthesis of these environmental and ecological concerns into the broader narrative of SFLO challenges illuminates the intricate relationship between forest management, climate change adaptation, and ecological resilience.

As SFLOs grapple with these issues, the need for comprehensive strategies that address the dual goals of environmental sustainability and economic viability becomes increasingly apparent. Collaborative efforts involving SFLOs, environmental experts, policy makers, and research institutions are essential in developing adaptive management practices, risk mitigation strategies, and policy frameworks that support the resilience of forest ecosystems in the face of climatic and ecological uncertainties.

The pathways forward require a concerted focus on integrating innovation, knowledge sharing, and policy support streamlined to empower SFLOs in their critical role as stewards of forest lands. By addressing these environmental and ecological concerns through a holistic and integrated approach, SFLOs

(particularly new and younger less experienced SFLOs) can more quickly learn to navigate the complexities of sustainable forest management, contributing to the overarching goals of climate mitigation, biodiversity conservation, and ecosystem health.

Theme: Navigating the Environmental Frontier

The patterns identified within the environmental and ecological concerns of Small Forest Landowners (SFLOs) converge into a shared theme characterized by the urgent need to navigate the complexities of the environmental frontier. This theme encapsulates the dual challenge of adapting to the immediate impacts of climate change and natural disasters, while also considering the long-term imperative to enhance biodiversity and regain ecosystem balance. It reflects a critical junction where the pursuit of sustainable forest management and climate mitigation efforts must be harmoniously aligned with the ecological realities of forest ecosystems. This intricate balancing act requires SFLOs to not only mitigate the adverse effects of environmental changes but also to actively contribute to the resilience and health of forest landscapes.

Navigating the Path Forward
The synthesis of these environmental and ecological concerns into the broader narrative of SFLO challenges illuminates the intricate relationship between forest management, climate change adaptation, and ecological resilience. As SFLOs grapple with these issues, the need for comprehensive strategies that address the dual goals of environmental sustainability and economic viability becomes increasingly apparent. Collaborative efforts involving SFLOs, environmental experts, policy makers, and research institutions are essential in developing adaptive management practices, risk mitigation strategies, and policy frameworks that support the resilience of forest ecosystems in the face of climatic and ecological uncertainties.
The path forward requires a concerted focus on innovation, knowledge sharing, and policy support to empower SFLOs in their critical role as stewards of forest lands. By addressing these environmental and ecological concerns through a holistic and integrated approach, SFLOs can navigate the complexities of sustainable forest management, contributing to the overarching goals of climate mitigation, biodiversity conservation, and ecosystem health.

This thematic analysis underscores a pivotal concern: the capacity of SFLOs to navigate these environmental challenges is intrinsically linked to their ability to access resources, knowledge, and support systems that enable effective adaptation and resilience-building measures. Therefore, it is critical that recommendations focus on rapidly increasing that needed capacity of SFLOs to not only engage in Climate Smart Forestry Practices but also convince their neighbors to join in the common effort.

Trends

Policy, Program, and Practice Recommendations

To specifically incentivize Small Forest Landowners to participate enthusiastically in Climate Smart Forestry Practices and the statewide carbon sequestration credit market, the following recommendations are proposed:

- Flexible Regulation Frameworks: Develop and implement regulatory frameworks that are flexible enough to accommodate the diverse conditions and capabilities of SFLOs, while ensuring environmental and ecological objectives are met.
- Carbon Credit Incentives: Establish clear, accessible, and equitable mechanisms for SFLOs to participate in carbon credit markets, including simplified verification processes and tiered participation levels to accommodate different sizes and types of forest lands.
- Risk Management Support: Introduce policies that provide financial and technical support for risk management and disaster preparedness, including insurance schemes and emergency response resources tailored to SFLO needs.

Program Recommendations

- Adaptive Management Training: Launch state-sponsored training programs focused on adaptive management strategies, climate resilience, and sustainable forestry practices, leveraging online platforms for wider accessibility.
- Biodiversity Conservation Grants: Create grant programs that specifically fund projects aimed at enhancing biodiversity and ecosystem balance within the context of carbon sequestration efforts.
- Collaborative Research Initiatives: Foster partnerships between SFLOs, academic institutions, and environmental organizations to drive research on innovative forestry practices that balance carbon sequestration with ecological health.

Practice Recommendations
- Community-Based Resource Sharing: Encourage the development of regional or local community-based resource sharing platforms that enable SFLOs to access equipment, expertise, as well as financial and social resources more efficiently.
- Best Practices Repository: Develop an online repository of best practices, case studies, and technological innovations in sustainable forestry and carbon sequestration, curated specifically for SFLOs.
- Mentorship/ Programs: Establish mentorship programs that connect novice SFLOs with experienced practitioners, facilitating knowledge transfer and capacity building within the SFLO community.

By implementing these recommendations, the aim is to equip SFLOs with the tools, resources, and support necessary to actively and confidently engage in Climate Smart Forestry Practices. In doing so, not only can SFLOs enhance their participation in carbon sequestration efforts, but they can also contribute to the broader objectives of environmental sustainability, biodiversity conservation, and climate resilience.

#5 Patterns: Market-Related Issues

Incorporating the identified set of patterns related to Market-Related Issues, in the narrative around the challenges faced by Small Forest Landowners (SFLOs) in adopting Climate Smart Forestry Practices deepens, particularly focusing on the hurdles related to market dynamics. These patterns elucidate the economic pressures further, complicating the viability of sustainable forest management for SFLOs. The addition of these patterns weaves into the existing themes,

emphasizing the intricate balance between environmental stewardship and economic sustainability:

Market Access and Viability:
SFLOs encounter significant challenges in integrating into existing carbon markets, compounded by the unpredictability and fluctuation of carbon credit prices. This difficulty in accessing markets and the instability of potential revenue streams add another layer of complexity to the financial constraints already highlighted, making it harder for SFLOs to commit to and invest in Climate Smart Forestry Practices.

Market Volatility:

The uncertainties in carbon and timber markets further exacerbate the financial risks for SFLOs. This volatility affects planning and investment decisions, as the returns on investments in sustainable practices become even more unpredictable. Such market fluctuations deter SFLOs from making the necessary upfront investments in sustainable forest management, given the lack of assurance on viable returns.

Scale Disadvantages:

The smaller scale of SFLO operations inherently leads to less efficiency and higher per-unit costs compared to larger forestry operations. This disadvantage affects not just operational efficiencies but also the ability to compete effectively in the market, particularly in carbon trading and timber sales. The scale issue ties back to the financial constraints and small ROI, as smaller operations find it challenging to achieve the economies of scale necessary for profitability.

Trends

Increasing Development Pressure and Fragmentation:

The development pressures leading to the subdivision of forest lands and the increasing number of owners for smaller parcels exacerbate the challenges of scale and market viability. As land parcels become smaller and the number of landowners increases, the difficulties in managing land sustainably and profitably grow. This trend amplifies the negative impact of high costs and low returns on investment, making sustainable forest management an even more daunting task for SFLOs.

These market-related issues highlight the systemic barriers to adopting Climate Smart Forestry Practices among SFLOs. The narrative underscores the need for comprehensive strategies that address market access, stability, and the inherent disadvantages of scale faced by small landowners. To mitigate these challenges, policies and programs must not only offer financial and technical support but also create more stable and accessible markets for carbon credits and sustainable timber forest products. This approach could help bridge the gap between environmental goals and economic viability for SFLOs, encouraging more widespread adoption of sustainable practices.

Theme: Market Complexities Hinder SFLOs engagement in Carbon Markets

The common theme emerging from the analysis of market-related issues faced by Small Forest Landowners (SFLOs) revolves around the intricate challenges of market access, volatility, scale disadvantages, and the impact of development pressures. These driving factors create a complex

environment that hinders SFLOs' ability to engage in and benefit from Climate Smart Forestry Practices and carbon markets.

Narrative

SFLOs are navigating a challenging landscape where the shared ambition to contribute to forest health and resilience is met with significant economic and operational hurdles. Market access and viability issues underscore the difficulty in participating in carbon markets, where fluctuating prices and the complexity of entry act as major barriers. Market volatility, with unpredictable swings in carbon and timber prices, further complicates financial planning and investment in sustainable practices. The disadvantages of operating on a smaller scale add to these woes, as smaller forest lands incur higher costs per unit and struggle with efficiency compared to larger operations.

Trends

The trend of increasing development pressure, leading to the subdivision of forest lands and a rise in the number of owners, which fragments the landscape and dilutes the potential for unified, large-scale action compounds these challenges. The overarching trend indicates a growing divide between the potential for SFLOs to contribute significantly to climate mitigation efforts and the reality of economic and market constraints that act as a disincentive and therefore limit their potential participation. This divide is exacerbated by the increasing fragmentation of forest lands, which not only affects the ecological integrity of forests but also diminishes the economic viability of sustainable forestry practices on a smaller scale. The trends suggest a need for systemic changes that address the unique position of SFLOs within the broader forestry and carbon market ecosystems.

Recommendations

Policy

- Establish Market Access Programs: Develop targeted programs that facilitate SFLO integration into carbon and timber markets. This could include aggregating land under cooperative models to improve market leverage and reduce entry barriers. Consider additional support from the USDA Rural Development Cooperative Grants to provide additional federal financial assistance for the development of Rural Climate Smart Forestry Cooperatives.

Programs

- Stabilize Market Volatility: Introduce financial instruments or subsidies that buffer SFLOs from the worst impacts of market volatility, ensuring a more predictable income stream from carbon credits and sustainable timber practices.
- Support for Scaling Operations: Provide technical and financial assistance to SFLOs aimed at improving operational efficiency. Encourage partnerships and cooperatives that enable SFLOs to achieve economies of scale. Look to USDA Rural Development Cooperative Grant for a model of this recommendation
- Incentivize Ecological and Economic Resilience: Develop incentive programs that reward SFLOs for practices that enhance forest health, biodiversity, and carbon sequestration. This could include tax breaks, grants, or higher prices for carbon credits and sustainably managed timber.

- Educational and Technical Support: Increase the availability of educational programs and technical support for SFLOs to navigate market systems, sustainable forest management practices, and carbon credit certification processes.
- Flexible and Accessible Financing: Create financing mechanisms that are tailored to the needs of SFLOs, including low-interest loans and grants for upfront investments in sustainable practices and infrastructure improvements.

By implementing these recommendations, there's potential to significantly mitigate the market-related complications faced by SFLOs, enabling them to contribute more effectively to climate change mitigation and sustainable forest management while also ensuring their economic viability.

#6. Patterns: Operational Challenges

The following set of patterns significantly impact the effectiveness of operations of Small Forest Landownership, including physical and labor limitations due to aging, management and labor constraints, as well as scale and property size limitations.

Physical Labor Limitations:

Aging SFLOs face normal decline in physicality yet face large physical challenges in managing forests, which varies by property size, type, locations, topography, and so on. Additionally, the need for an enormous amount of hard labor on the front end of Climate Smart Forestry Practices will likely outstrip the capacity of most owners of retirement age.

Management and Labor Constraints:

Limited resources for management, costly hard-to-find labor, aging retired landowners with fixed incomes, and physically labor-intensive tasks.

Scale and Property Size Limitations:

Smaller properties face challenges in achieving economies of scale and qualifying for programs whereas larger scale properties have more advantages. That said, even smaller properties provide significant challenges upon start-up of new forestry management plans.

These challenges collectively hinder the effective and sustainable management of forest lands, particularly impacting the SFLOs ability to participate in beneficial Climate Smart Forestry Practices and carbon sequestration markets.

Theme: Operational Hurdles must be overcome to launch Climate Smart Forestry Plans

SFLOs grapple with a range of operational hurdles that complicate their stewardship of the land. Management and labor constraints are at the forefront of this theme, with limited resources available for effective management and an aging demographic of landowners who often operate on fixed incomes. These constraints are further exacerbated by the labor-intensive nature of forestry practices. The issue of

scale and property size also plays a critical role, as smaller properties struggle to achieve economies of scale, making it difficult to qualify for various forestry programs and incentives that are more accessible to larger properties. Moreover, physical and labor limitations become increasingly relevant as the SFLO population ages, facing a decline in physical capability while still confronting the substantial physical demands of forest management, which can vary significantly based on property size, type, location, and topography.

Trends

- SFLOs are aging out of active hard labor and investment in sweat equity
- SFLOs who are aging out struggle to develop adequate succession plans as many do not have heirs, and either have to sell or consider passing the land on to Land Trusts.
- "...25,000-50,000 SFLO area likely anticipating selling all or some of their forest land in the coming 10 years. Somewhat fewer than 1 in 10 current SFLOs have likely ever sold or given away some, but not all of their forest land."
- Supply of available and affordable labor is short
- Heavy Equipment that could help ease the harder aspect of labor are getting more expensive as inflation has pushed up costs.

The trends highlight a growing concern over the sustainability of small-scale forestry operations, particularly as the population of SFLOs ages. The operational challenges underscore a broader issue of accessibility and inclusion in forestry management programs and initiatives aimed at promoting sustainable practices and climate resilience. As these challenges persist, there is a risk of increased forest land fragmentation and a decline in the overall health and resilience of forest ecosystems, which can have wider environmental and economic implications.

Recommendations

- Enhanced Technical Assistance Programs:
  - Implement comprehensive technical assistance programs aimed at SFLOs to provide management guidance, labor solutions, and advice on achieving operational efficiencies, tailored to the unique challenges of small-scale operations.
- Incentivize Cooperative Models:
  - Encourage the formation of cooperatives or collective management groups among SFLOs to pool resources, share labor, and achieve economies of scale, making it easier to qualify for forestry programs and access markets.
- Adapt Program Qualifications:
  - Adjust the qualifications for forestry programs and incentives to be more inclusive of smaller properties and those managed by aging landowners, ensuring that programs are accessible to a broader and more inclusive range of SFLOs.
- Labor Support Initiatives:
  - Develop initiatives that provide labor support to SFLOs, such as subsidized labor pools or volunteer programs geared towards forestry management, specifically designed to address the labor-intensive nature of the work and the physical limitations of aging landowners.
- Aging Landowner Support:

- Create support programs specifically for aging SFLOs, offering solutions that address their unique physical and operational challenges, including grants for mechanization aids that reduce physical labor requirements.
  - Education and Training:
    - Offer targeted education and training programs for SFLOs on sustainable forest management practices that are tailored to the operational and physical capabilities of small-scale and aging landowners.
  - Flexible Funding Mechanisms:
    - Provide flexible funding and grant programs that support the operational needs of SFLOs, including investments in labor-saving technologies and practices that can help overcome the challenges associated with scale and physical limitations.

By addressing these operational challenges through targeted policies, programs, and practices, there is an opportunity to significantly improve the sustainability and resilience of small-scale forestry operations. These recommendations aim to empower SFLOs to overcome the barriers they face, ensuring their valuable contribution to forestry management and climate resilience efforts.

#7. Patterns: Socioeconomic Factors

The identified patterns within the socioeconomic factors highlight the intricate interplay between socio political climates, cultural values, social pressures, and community dynamics, and their impact on Small Forest Landowners (SFLOs). These driving factors, perceptions if you will, collectively influence social distance in relationships as well as the decision-making process regarding forest management practices. These factors impact the ability of SFLOs to gather and align their operations with ecological values, economic sustainability, and community expectations.

Sociopolitical Climate:

Impact of local economic decline, property value changes, and political differences create additional tension, at times divisiveness, and tentativeness to sustaining trusting relationships across the social fabric of rural forestland society. This can make it difficult to present a unified front to advocate for the shared interests of Small Forest Landowners.

Cultural Values vs Social Perceptions of Difference:

Aligning management practices with a range of cultural and social values that differ from among SFLOs that manage their land for ecological value different from those committed to farm forestry. On the surface, this perception of difference can be magnified by the relative social isolation, private way of life rural folks value. Conversely, it should be said, both in interviews and additional survey research confirm that the majority of SFLOs share common values for their forest's health, natural beauty, scenery, provision of wildlife habitat, protection of water resources, environmental benefits, privacy and personal attachment to the land. Certainly, there is common ground to be held among SFLOs whether they practice timber harvesting or ecological preservation.

Community Dynamics:

Interactions with rural neighbors, local community engagement, and varying attitudes, opinions and bias towards different forest management practices create conditions that, in particularly remote areas, cause some SFLOs to engage socially with caution, as these factors decrease a sense of personal safety the

perception of political differences creates.

Theme: SFLO Perceptions of Differences and Common Ground

SFLOs operate within a complex socioeconomic context that significantly influences their approach to forest management. The sociopolitical climate, marked by local economic decline and fluctuations in property values, alongside political differences, sets the backdrop against which SFLOs navigate their local operational strategies. This climate can either facilitate or hinder the adoption of sustainable practices, depending on the degrees of tensions experienced in the local economic, political and social fabric of rural life. Furthermore, the alignment of management practices with cultural values and social pressures presents a nuanced challenge.

SFLOs face the task of balancing ecological management objectives with the expectations and values of their communities, which may vary widely. Some in their communities may prioritize farm forestry for its immediate economic benefits, while others may lean towards long-term ecological value. This dichotomy is compounded by community dynamics, including interactions with neighbors and local community engagement, which vary significantly in their attitudes and opinions towards these two different forest management practices. In particularly remote areas, these dynamics can lead to social caution among SFLOs, as varying attitudes and biases may affect their sense of personal safety and willingness to engage in certain management practices. That said, it bears repeating again, underline{both in interviews and additional survey research confirm that the majority of SFLOs interviewed share common values for their forest's health, natural beauty, scenery, provision of wildlife habitat, protection of water resources, environmental benefits, privacy and personal attachment to the land.} Certainly, there is Signiant **common ground** to be cultivated among SFLOs whether they practice timber harvesting or ecological preservation. This common ground, as one special Forest Service Employee who has visited more SFLOs than anyone this researcher interacted with put it, "...most SFLOs really want to do the right thing." With a number of SFLOs, they share sentiments that can be summed up by saying, eventually the forest teaches us what "doing the right thing" is by successes and failures.

Trends

The larger societal trends suggest a growing need for SFLOs to navigate socio economic/ Socio political challenges with strategic agility. As societal values evolve and the emphasis on sustainable and ecological forest management gains momentum, SFLOs are increasingly required to balance these external pressures with their operational capabilities, objectives and political sensibilities. The impact of this set of socioeconomic factors is not uniform but varies greatly depending on local contexts, highlighting the importance of adaptable and community-sensitive approaches to forest management.

Recommendations

Community-Based Planning and Decision-Making:

Facilitate community-based planning and decision-making processes that include SFLOs, local residents, and other stakeholders. By involving the community in the planning process, SFLOs that care can better align their social relationships with their management practices when it comes to better understanding shared local values and expectations, enhancing community support and cooperation.

Community Engagement Initiatives:

Develop programs that foster dialogue and collaboration between SFLOs and their communities, aiming to bridge gaps in understanding and expectations regarding forest management practices. These initiatives could facilitate mutual understanding and support for diverse management objectives.

Intercultural Training:

Offer training and resources to SFLOs on community engagement strategies that help increase intercultural relations. This would equip neighboring SFLOs with the skills to navigate the complex dynamics of cultural values and social pressures, economic perspectives by fostering more harmonious interactions and decision-making. It would also help folks recognize their shared values and the common ground between SFLOs. Organizations like Washington Farm Forestry Association have the opportunity to help in this space, yet the name baring "Farm" may be a deterrent to those SFLOs who are unaware of the common ground WFFA has been cultivating for decades.

Safety and Well-being Programs:

Recognize and address the concerns related to personal safety and social caution among SFLOs in remote areas by establishing programs focused on enhancing safety, promoting inclusivity, and mitigating conflicts arising from differing views on forest management.

By addressing the socioeconomic factors through these recommendations, there's potential to enhance the resilience and sustainability of SFLO operations while fostering positive community relations and support for diverse forest management practices. These measures aim to create a more inclusive, adaptive, and socially sensitive approach to forest land management, reflecting the complex interdependencies between SFLOs and their socioeconomic environments.

Socioeconomic Support Programs:

Implement support programs tailored to the specific socioeconomic challenges faced by SFLOs, such as grants or subsidies to mitigate the impact of local economic decline or incentives for practices that align with shared values for forest health, wildlife diversity and habitat as well as water resources.

Adaptive Management Frameworks:

Encourage the adoption of adaptive management frameworks that allow SFLOs to adjust their practices in response to changing socio political climates, cultural values, and community dynamics. This approach would enable SFLOs to remain flexible and responsive to external pressures.

The values behind the socially and culturally oriented recommendations for this theme should not be understated as the keys to incentivizing SFLO engage do not rest on financial and technical assistance alone. The role of highly valued shared commonality can help build and strengthen the common bonds required to reinforce the rapid social adoption critical to effectively launching a new carbon sequestration credit market, and more importantly spread the rapid adoption of Climate Smart Forestry Practices among the communities of Small Forest Landowners in Washington. Policies, Programs and Practices that reduce the perceptions of differences vs by increasing the knowledge of shared common ground are likely to be one of the most significant drivers of changing old thinking and old behaviors with new ways of seeing and caring for the forest and the trees.

#8. Patterns: Long-Term Planning and Succession Issues

Land continuity planning and succession, particularly in family-owned forests, were of particular concern to all aging SFLOs interviewed. The majority of interviewees either did not have a relative for the property to be passed on to or no plan as of yet what kind of succession plan would honor their continued desires and wishes for the continued management of their forests. The SFLOs in this situation most frequently used the word "Land Trust" somewhat generically as a possible option but were scant on the specifics of what type of Land Trust would fill this gap in long-term forest planning. They were, to a degree, unsure whether land trusts would or could hold and honor their wishes or, in two comments about common Land Trust practices, were concerned their properties would be sold and the income used to manage forest land considered higher value.

Complex Land Succession Problem

Many SFLO are aging and need to plan for the future of their land when they are gone. In doing so they are confronted with a complicated set of choices that all seem like variations of bad to worse choices.
- Selling land that is sub optimal for development does not provide a Return on Investment that is proportional to the love, care and labor they have put into it because of the Forest Designation back taxes reduce the value of the land substantially.
- Gifting their Forest to a land trust does not guarantee the land will be retained (not sold) and cared for in a way the original owner desired.

Future Uncertainties:

Concerns about the long-term viability and value of carbon sequestration efforts.
The most redundant issues across the documents are financial constraints, regulatory and policy challenges, and technical knowledge gaps. Environmental concerns and market-related issues are also prominently mentioned, followed by operational and socioeconomic factors. Long-term planning, succession issues, and individual perspectives provide more specific insights but are less redundant overall.

Theme: Uncertain Future of Small Forest Land Succession

The set of related patterns identified within the realm of long-term planning and succession issues for Small Forest Landowners (SFLOs) underscore the complexity of ensuring land continuity and the perpetuation of desired forest management practices. These concerns are particularly pronounced among aging SFLOs, who face challenges in passing their land to the next generation or finding suitable mechanisms, such as land trusts, to honor their forestry management wishes after their passing.

Narrative

Aging SFLOs are increasingly concerned with the future of their forests, especially in the absence of direct heirs or clear succession plans that align with their ecological and forestry management values. The concept of land trusts emerges as a potential solution, albeit with reservations regarding the trusts' ability to faithfully execute the original owners' wishes and the risk of the land being sold for other purposes. This dilemma is further complicated by the financial implications of selling forest land, which may not reflect the true value owners attribute to their years of stewardship due to factors like forest designation back taxes. Additionally, legal and ownership complexities, such as inheritance laws and fragmented ownership, pose significant barriers to smooth land transition. Uncertainties about the future viability of carbon sequestration and its role in long-term forest value exacerbate these planning challenges.

Trends

The trends reveal a pressing need for innovative solutions that can bridge the gap between SFLOs' desires for their land's future and the practical mechanisms available to secure these outcomes. There's a growing recognition of the importance of developing specific strategies that cater to the unique needs of SFLOs, particularly those without direct succession options, to maintain the ecological and economic value of their forests in the long term.

Recommendations

Policy

Create a Climate Smart Land Trust Designation and Certification:

Implement a certification system for land trusts that demonstrates their commitment to Climate Smart Forestry Practices, providing SFLOs with the confidence that their land will be managed according to their wishes.

Incentivize Land Donation:

Create tax incentives and other benefits for SFLOs who choose to donate their land to conservation efforts or land trusts dedicated to sustainable forestry practices, ensuring their legacy and the land's ecological value are preserved

Programs

Develop Climate Smart Land Trusts:

Establish land trusts specifically designed to support Climate Smart Forestry Practices, offering SFLOs a reliable option to entrust their land to an entity committed to upholding their ecological and management values. Climate Smart Land Trust focusing its efforts on sustaining "Climate Smart Forestry Practices" that would enable SFLOs, without a succession plan, to secure a long-term forestry plan that sustains their common values for forest health and resilience… SFLO have worked toward much of their lives on the land. This may include an intermediate heir to confidently eventually entrust their land to a responsible agency.

Enhance Legal and Financial Guidance:

Provide SFLOs with access to specialized legal and financial planning services that can navigate the complexities of land succession, focusing on maximizing the preservation of the land's ecological and economic value.

Educate SFLOs on Succession Planning:

Launch educational programs aimed at SFLOs to highlight the importance of early and effective succession planning, offering tools and resources to develop plans that reflect their forestry management goals.

Work with legal experts to simplify inheritance laws and address issues of fragmented ownership, making it easier for SFLOs to plan for the future of their land.

Support Research on Long-Term Viability of Carbon Sequestration:

Fund research to better understand the long-term impacts and benefits of carbon sequestration efforts, providing SFLOs with information that can inform their succession planning.

By implementing these recommendations, there's potential to significantly alleviate the concerns of SFLOs regarding long-term planning and succession, ensuring that their land continues to be managed in a way that honors their commitment to sustainable and Climate Smart Forestry Practices. In addition, many of these steps can help reverse the disaggregation of Forest Lands into smaller and smaller partials making the Carbon Sequestration Credit Market and Climate Smart Forestry Plans and Practices much harder and more expensive and time consuming to deploy effectively. These measures aim to provide clarity, support, and viable options for SFLOs as they navigate the complexities of ensuring their forests' future.

Summary: Future Scenarios of Small Forest Landowner

Before the presentation of the formal research findings the two future scenarios are presented below to better familiarize the reader, in narrative story form with what the future of Small Forest Landowners imagines to be in 2044. While there may be subtle imaginative differences from one SFLO to another, the general composite scenarios are directly supported by the interview data as well as other survey research and trend analysis.

Undesirable Future Scenario for Small Forest Landowners:

In the year 2044, the small forest land ownership landscape has drastically transformed, and not for the better. The Pacific Northwest, once a lush expanse of greenery and life, is now a stark representation of the consequences of neglect, environmental degradation, and the cascading effects of climate change.

At the heart of this undesirable future are the small forest landowners (SFLOs), who find themselves battling an array of challenges that threaten the very existence of their lands. The changing climate has wrought havoc on the weather patterns, with summer droughts becoming more severe and dry winds ravaging the lands. Winters, once blanketed in snow, now see a significantly reduced snowpack, disrupting not only human activities but also the delicate balance of the forests.

Wildfires, fueled by the dry conditions and exacerbated by a lack of proactive forest management, sweep through the region with increasing frequency and intensity. Overstocking and short-sighted exploitation for economic gains have left the forests vulnerable, reducing their ecological value and sustainability. Invasive species, diseases, and wildfire incursions further degrade the landscape, while development pressures from growing urban populations encroach upon the forests, fragmenting the land into ever smaller and less healthy parcels. This fragmentation undermines the privacy, beauty, wildlife corridors, and ecological health that were once the pride of the region.

As urban areas expand, the demand for rural homes and second residences skyrockets, putting additional pressure on these small forests. The natural habitats that are crucial for the survival of both terrestrial and aquatic species are threatened, jeopardizing the biodiversity that once thrived in these woods.

Compounding these issues is the demographic shift among the SFLOs themselves. Many of the older landowners do not have heirs willing or able to take over the stewardship of these forests. Consequently, the lands suffer from neglect, becoming even more susceptible to diseases, fires, and invasive species. The challenge of regenerating new forests is daunting, as native trees struggle to adapt to the changing climate conditions.

Amidst these challenges, there is a growing recognition of the need for biologically sustainable and climate-smart forest products. The move away from petroleum-based plastics and chemicals has increased the demand for these products, yet the ability of SFLOs to meet this demand is hindered by the deteriorating condition of their lands.

For those with larger tracts of land, government intervention and restrictive land use policies add another layer of complexity. What was once seen to protect and preserve the land is now viewed as a constraint, limiting the owners' ability to respond effectively to the myriad challenges they face.

This is the stark reality of small forest land ownership in 2044. The cumulative impact of climate change, urban expansion, and socio-economic shifts has created a landscape that is a shadow of its former self. The dreams and aspirations of the SFLOs have been replaced by a struggle for survival, as they grapple with the consequences of an undesirable future that has become their reality.

Desirable Future Scenario for Small Forest Landowners:

In 2044, the landscape of small forest land ownership has transformed into a vibrant tapestry of resilience and sustainability, thanks to the harmonious blending of innovative land management strategies and related climate-smart forestry practices. This narrative unfolds a future where the once daunting challenges posed by climate change and urban expansion have not only been mitigated but have paved the way for a rejuvenated and ecologically sound forest management paradigm.

Two decades ago, the Pacific Northwest faced the relentless fury of climate change—extreme weather events, invasive species, and the specter of wildfires threatened the very fabric of forest ecosystems and communities. Today, those privately owned small forests stand as bastions of resilience, with small forest landowners (SFLOs) at the helm of a remarkable turnaround. Adopting climate-smart forestry practices, these spirited and adaptable guardians of the green have woven a protective shield around their lands, enabling their forests to sequester additional carbon, repel the threats of wildfires, and support a burgeoning ecosystem teeming with life and human habitation.

The driving force behind this transformation has been a collective shift towards sustainability and ecological stewardship. The establishment of a robust carbon sequestration credit market over 18 years ago provided the necessary financial incentive, encouraging SFLOs to prioritize long-term ecological health, forest resilience and the optimal sequestration of carbon over short-term gains. This market not only reversed the tide of overstocking and exploitation but also infused new life into the rural economies, rewarding landowners for their contributions to the planet's health.

Moreover, the narrative of small forest land ownership has been enriched by the influx of new owners, drawn by the allure of rural privacy, natural tranquility and the promise of contributing to a greener planet. Much like their forebears, these environmentally conscious individuals have gradually aggregated smaller parcels into larger tracts, establishing rural homes that serve as sanctuaries for both people and wildlife. Their participation in the state's carbon sequestration market has accelerated the restoration of wildlife habitats and bolstered the resilience of terrestrial and aquatic species against the backdrop of urban expansion.

The transition of ownership has also addressed the looming specter of neglect that once threatened these forests. As older SFLOs exited the scene, without heirs to continue their legacy, the potential for decline

loomed large. However, the combined allure of state incentives and a growing recognition of the value of sustainable forest products has attracted a new generation of landowners. These individuals have not only taken up the mantle of stewardship but have also driven innovation in the production of carbon-neutral forest products, aligning with global efforts to reduce reliance on petroleum-based materials.

This future scenario reflects a world where government intervention has been balanced and strategic, avoiding overly restrictive land use policies that could stifle innovation and growth. Instead, SFLOs, especially those with larger acreages, have found a supportive framework that encourages sustainable management without imposing undue burdens.

As we gaze upon the forests of 2044, we see more than just trees; we see a living testament to human flexibility, ingenuity, resilience, and an unwavering commitment to their forests and the planet. The small forest landowners of this era have not only adapted to the challenges of their time but have also laid the groundwork for a future where forests thrive, economies flourish, and a cooler planet breathes a little easier.

While there is some variation in this common scenario for practicing SFLOs who additionally harvest trees for economic gain, the general value and positive sentiment for their forest lands are held in common. It turns out in this future that a critical aspect of healthy and resilient forests requires regular scientifically informed and targeted thinning and some degree of harvesting to improve the forests' ability to sequester more carbon than the once neglected forestlands.

Conclusion:

The report concludes with a nuanced understanding of the various factors influencing SFLOs' decisions regarding forest management and carbon sequestration. It highlights the critical need for policy adjustments, educational support, and technical assistance to overcome the barriers to participation thereby decreasing the disincentives to engagement. The study's recommendations focus on creating an enabling environment for SFLOs, ensuring their practices are both sustainable and economically viable. By addressing these recommendations, there is a potential to significantly increase SFLOs' engagement in carbon sequestration efforts, contributing to Washington State's broader environmental and climate mitigation goals. In the end this study suggests that a balanced approach to policy, programmatic and practice-oriented recommendations that work to reducing the key barriers SLFO perceive as critical disincentives to participation and increasing targeted incentives that ensure the success and rapid adoption of a new carbon credit market that supports SFLOs Climate Smart Forestry Practices. Of major importance to developing such an important and large-scale program is to emphasize the shared common ground that is held in high values of the SFLOs who participated in this study and confirmed by other relatively recent research. That common ground is the shared value for a desirable future where people and wild things can enjoy care for the beauty, scenery, tranquility and privacy of their forests where the wildlife habitat, that are fundamental environmental benefits that come from healthy water resources and resilient forestlands.

Continued Research Suggestions

Inclusion of Underrepresented Populations: Environmental Justice, Diversity, Equity, Inclusion,

Future research should prioritize strategies for including underrepresented populations

among SFLOs, focusing on racial, ethnic, socioeconomic, and gender diversity to ensure equitable participation in carbon sequestration programs.

The potential for synergies between carbon sequestration and poverty alleviation exists, with many land-use changes accessible to low-income land users being competitive in carbon markets. Sequestration payment sources and the design of payments to overcome constraints such as risk or investment barriers are important for enhancing the participation of the poor and maximizing the benefits of sequestration projects (Lipper & Cavatassi, 2004).

Long-Term Impact Studies:

Investigate the long-term environmental and economic impacts of carbon sequestration practices among SFLOs to better understand the sustainability and efficacy of current policies and programs.

Behavioral Insights:

Apply behavioral science to explore the motivations and barriers for SFLOs' participation in carbon sequestration, aiming to design more effective incentives and communication strategies.

Technological Innovations:

Research the role of technology in facilitating SFLOs' engagement in carbon sequestration, including the use of digital tools for forest management and carbon credit trading.

Comparative Studies:

Conduct comparative studies with other states or countries with similar forestry contexts to identify best practices and innovative approaches to engaging small forest landowners in carbon sequestration.

Impact of Climate Change:

Examine how evolving climate conditions affect SFLOs' land management practices and their capacity to participate in carbon sequestration efforts.

Policy and Regulatory Framework Analysis:

Assess the impact of existing policies and regulations on SFLOs' participation in carbon markets and identify potential areas for reform to reduce barriers to entry.

Economic Viability Studies:

Explore the economic viability of carbon sequestration for SFLOs, including cost-benefit analyses and potential for income diversification through carbon credits.
These suggestions aim to build upon the foundational work of this research, deepening our understanding and enhancing the engagement of SFLOs in carbon sequestration and sustainable forest management practices.

Detailed Methodology

- ○ In-depth description of the research methods used.
- ○ Additional details about participant demographics, selection criteria, and data collection processes.

- **Data Analysis Techniques and how they support futures forecasting.**
  - ○ **Constant comparative analysis** is a core method used in qualitative research, particularly grounded theory, to analyze data systematically. The following research uses this iterative process which involves comparing each piece of data (e.g., interview transcripts, observations, or documentary materials) with every other piece to identify similarities and differences. The process begins by organizing and sorting the initial data, sometimes adding identifying codes, then assigning labels to chunks of data that represent shared concepts, searching from shared patterns of thinking, behavior, perceptions. Groups of related patterns describe key themes by which insights and recommendations are produced for the applied research.
  - ○ As more data is collected and analyzed, these codes/labels are compared and refined, leading to the development of categories that describe these codes. These categories are then constantly compared against new data and against each other to refine their properties and identify underlying patterns and relationships. This ongoing process of comparison helps in developing a grounded theory that emerges from the data, offering a deep, nuanced understanding of the phenomena under study. Through constant comparative analysis, this research aims to ensure their findings are rooted in the interview data itself, enhancing the credibility and depth of their qualitative analysis. Later, the results of this process can be compared and contrasted to larger data sets from a mix of other methods that have been used to better understand Small Forest Landownership in the State of Washington.
  - ○ A **Constant Comparative Analysis** process is used for each interview as the interviewing process progresses. As new information is gathered from the EFR interviews, it is analyzed and matched with existing information to form a bigger picture. Patterns are identified from the collected data and are then classified into categories. This process involves organizing data by sorting and labeling it. In the constant comparative method, **actively looks for recurring themes and labels each piece of information based on the categories it fits into.** For the sake of this report, given the limited budget, the process has been condensed to render **Themes, Insights, Recommendations,** that are most often shared by the sample of informants.
  - ○ During the data collection process, the data from each interview is also constantly engaged in analysis that eventually shows repeated patterns of similarities and

differences. A related collection of patterns makes up this theme. Once a sufficient number of interviews have been conducted, the data and analysis begin to demonstrate repeated confirmation of the patterns and themes. When no substantially new patterns, themes, and insights emerge, the data collection process and results have achieved a degree of analytical saturation. In this brief study the data collection and analysis has reached a degree of confidence that the study has effectively captured the range of Small Forest Landowners Perspectives in the heterogeneous sample.

○ That said, without additional samples of informants from traditionally underserved and/or vulnerable populations, tribal entities or rural poor, no conclusive statement about analytical saturation can be made about nor can this study extend the generalizations to these populations.

Extended Data and Analysis

○ Full datasets or detailed data tables that support the research findings.
○ Extended analysis, including additional themes or patterns not highlighted in the main summary.

Ethical Considerations and Permissions

○ Documentation of ethical considerations, approvals, and consent forms used in the research.
○ Details of how participant privacy and data security were ensured.

Constraints of Research

The following are internal and external factors that act as constraints this study endeavored to accommodate for and are considered in the final research alignment of methods to meet the goals and objectives of this contract.

● 1.) large size of the population of SFLOs, 218,000 in number are nearly as large as the population of Spokane, the second largest city in Washington State.
● 2.) broad geographic range of SFLOs across the entire state of Washington
● 3.) reliable internet access is likely to be uneven across the rural locations of informants to conduct remote interviews and data collection thus some onsite/in person interviews will likely be necessary.
● 4.) contrasting and potentially strongly held opinions, attitudes, bias, values, beliefs, and behaviors of the sample population may require some need to adapt and adjust the methodology to have the type and quality of data needed to analytically tease out discreet incentives and disincentives for different types of SFLOs. Thus, to complement the EFR interviews a range of mixed methods like short questionnaires, short interviews, and/or focus group will provide backup to the primary research strategy.

- 5.) Challenging situation in locating "underrepresented" or "non-traditional" Small Forest Landowners without a comprehensive census and contact database for the estimated 218,000 SFLOs means extra costs in time and resources committed to ensuring Diversity, Equity and Inclusion requirements of environmental justice being met.
- 6.) Challenge of selecting a representative sample of informants willing to participate across these

Explanation of the stakeholder landscape and potential impacts of the research findings.

Criteria For Effective Incentives

- Along with the fair and common assumption that to participate in a Statewide Carbon Sequestration Credit Market for Small Forest Landowners they would have to likely do something more to care for and manage their forestlands, like more Climate Smart Forestry Practices. Note: There was no commonly reported assumption that SFLOs would just receive any incentives just for letting their already existing standing trees grow with no management practices.
- To qualify as an effective incentive- a recommendation needs to strike a balance between reducing the perception of the RISK due to Uncertain profitability carbon credit markets and lesson the disincentive, the negative impact, of the perceived High Cost per acre to enter and sustain compliance with Certified Climate Smart Forest Management Plan with a range of highly valued incentives that include-
    - Financial benefit equals to the value of the effort (work) being done to participate.
    - The added economic benefits from the sales of forest resources- Due to additional expenses of timber removal, transportation, increasing distance to lumber mills and limited access to markets, the Forestland Designated tax obligation, not to mention the overall negative impact of inflation have all acted to lowing returns on forest resources sold.
    - The sale of the forest land itself given the present expected low return on their respective investment due to several factors, 1.) having to pay back taxes on the Forest Designation for not harvesting trees when property is sold. 2.) If the Forest is harvested before sale of the property, the property value will be at its lowest margin.
    - This is even a larger access and equity challenge for those folks on the Eastern side of the Cascades, and for the most remote locations on the Westside like those folks living on heavily forested islands. SFLOs caution that in these more challenged locations and conditions remark how such carbon sequestration credit programs for SFLOs could have the unintentional consequences of creating a greater socioeconomic divide of haves and have nots.
    - Technical Assistance that, without undue bureaucratic complication, provides a timely Climate Smart Certified Forestry Plan that, if practiced, would lead to measurable increase in carbon sequestered in their small forest lands enhanced forest health including natural beauty, wildlife habitat, privacy and ecological benefits
    - Increased forest resilience- reduced threat to fire, drought, disease, and invasives and possibility floods in some regions of the state.

○ Increased ROI for a more mature and healthy harvest with less loss due to the threats mentioned above

Future Research Directions: Recommendations for Continued Research

Recommendation 1: Enhancing Demographic Representation in Future Research

Current Limitation:

The current study, due to budget constraints and the homogenous nature of the informant population, lacks representation from traditionally underrepresented groups in terms of race, ethnicity, and socioeconomic status.

Recommendation:

Objective: Increase demographic diversity in future research on Small Forest Landowners (SFLOs).

1. **Budget Allocation:**
   o Secure additional funding to ensure the inclusion of diverse demographic groups, specifically targeting tribal reservations and low-income populations.
2. **Strategic Sampling:**
   o Collaborate with community organizations and tribal authorities to identify and recruit SFLOs from underrepresented backgrounds.
3. **Outreach and Engagement:**
   o Develop culturally sensitive outreach programs to build trust and encourage participation from diverse groups.
4. **Data Collection:**
   o Ensure that future studies incorporate a representative subsample that includes varied racial, ethnic, and socioeconomic backgrounds.
5. **Analysis and Reporting:**
   o Analyze data with a focus on identifying unique challenges and opportunities faced by underrepresented SFLOs.
   o Provide specific policy recommendations to address these challenges and promote inclusivity in climate-smart forestry practices.

Recommendation 2: Addressing Generational Succession in Small Forest Land Ownership

Current Limitation:

The current research highlights a significant challenge: the aging population of SFLOs and the lack of interest from younger generations in taking over forest management.

Recommendation:

Objective: Investigate barriers and develop strategies to engage younger generations in Climate Smart Small Forest Management and Carbon Sequestration Markets.

1. **Targeted Research:**
   o Conduct studies focusing on individuals under 50 years old to understand their perspectives, barriers, and motivations regarding SFLO engagement.
2. **Barrier Identification:**
   o Identify specific constraints, such as financial, educational, and lifestyle preferences, that deter younger generations from participating in forest management.
3. **Incentive Programs:**
   o Develop incentive programs to make SFLO roles more attractive to younger individuals, including financial support, education, and career development opportunities.
4. **Workforce Development:**
   o Create training programs and apprenticeships focused on climate-smart forestry practices, aiming to build a skilled workforce for the future.
5. **Policy Recommendations:**
   o Propose policies that address succession planning, providing support for current SFLOs to transition ownership to interested younger individuals.
   o Encourage legislative actions to facilitate smoother transitions and reduce barriers to entry for the next generation.

By implementing these recommendations, future research can be more inclusive and effectively address the challenges faced by SFLOs, ensuring sustainable forest management and participation in carbon markets.

Appendix 5: WA State Landowner Survey for Carbon Sequestration Pathways

The Carbon Workgroup conducted a survey of WA State SFLOs in 2023 that was introduced with the following explanation:

> *"This survey is intended to gauge forest landowners' interest in programs and practices to increase carbon sequestration on their land.*
> *The information gathered by this survey will be used to recommend policies and programs to the WA State Legislature, and to expand the ecosystem services marketplace for forest landowners.*
> *With a more detailed understanding of landowners' capabilities and interests in adding carbon sequestration to their suite of management activities, we can propose more effective and accessible programs for landowners.*
> *The ranges of potential financial compensation for carbon sequestration practices listed below represent what might be expected with existing and future carbon offset and other incentive programs.*
> *This survey does not include personally identifiable data and it will be used in aggregate to understand the dynamics and desires of the diverse forest landowner community."*

The survey had three components:

1. Basic demographic information including forest parcel size and location (Westside/Eastside).

2. Landowner management priorities (similar in both the categories and responses to the National Woodland Owners Survey)

3. Willingness to implement practices for increasing carbon sequestration and acceptable levels of financial compensation for:

   a. Afforestation

   b. Improved Forest Management

   c. Extended Harvest Rotation

   d. Legacy Forest Management

   e. Wildfire Resilience

The responses on management priorities confirmed the diverse interests of SFLOs as found in many previous surveys. Any new focus on carbon sequestration will be balanced with other ecological and financial objectives.

Forest Management Priorities:

	High	Medium	Low
Timber Products	64%	22%	14%
Non-Timber Products	6%	43%	51%
Land Investment	31%	18%	51%
Wildlife/Nature/Water Protection	65%	35%	0%
Recreation	37%	47%	16%
Carbon Sequestration	29%	50%	21%
Hunting/Fishing	18%	30%	52%
Privacy	51%	33%	16%
Beauty or Scenery	66%	28%	6%
Family Legacy / Raising	58%	24%	18%

The survey did not address barriers or concerns, which are extensively discussed in Guy Trombley's work as part of the Carbon Workgroup final report. This was essentially a "What If?" exercise: "Would you be willing to do this practice if you were financially compensated?"

Two landowner groups were surveyed:
1. WA Farm Forestry Association (WFFA) Annual meeting in May 2023:

    a. 36 respondents out of approx. 100 forest land ownerships (36% response rate)

    b. Actively managing, dues-paying members: 65% certified - all ATFS and some FSC

2. WSU Forest Owners Field Day in NE WA and other tree farm tours in June 2023:

    a. 20 respondents out of approx. 100 forest land ownerships (20% response rate)

    b. Engaged landowners attending educational events: 33% certified - all ATFS and some FSC

Missing from Survey: Non-managing landowners (which would have difficulty answering questions about forest management practices and associated financial considerations).
Results were aggregated for each survey group and then combined.
Results were then segregated by Westside and Eastside ownerships.
Similar results were found across all groupings with some notable/predictable differences.

Key takeaways:
1) There is strong SFLO interest in all proposed carbon pathways (67-88% participation willingness)

2) SFLO are willing to meet "half-way" on financing – SFLOs don't always require full compensation for implementing new practices (accepting a minimum 52-66% cost share)

Snapshot of selected key survey results:

Summary of Carbon Workgroup Small Forest Landowner Survey - 2023

Participation Willingness - Percentage of Respondents Answering "Yes"

Intervention Type	Westside	Eastside	
Afforestation	70%	67%	
Improved Forest Management	88%	89%	
Extended Rotations	71%	73%	
Legacy Forest Management	84%	83%	

Participation Cost - Weighted Mean of Minimum Acceptable Compensation for Intervention

Intervention Type	Westside	Eastside	
Afforestation	55	66	**Percent of cost of implementation**
Improved Forest Management	52	57	**Percent of cost of implementation**
Extended Rotations	6	5	**Percent of timber value paid anually for deferred harvest**
Legacy Forest Management	55	62	*** Percent of total timber value for one-time compensation**

* NOTE: Large percentage of Westside respondents for Legacy Forest Management compensation were unsure and didn't specify an acceptable value, potentially skewing the mean downward compared to the Eastside, which had no such uncertainty.

Forest management pathways with potential carbon benefit

Three Metrics to evaluate forest carbon sequestration effectiveness:
1. Optimize CO2 sequestration rate up to site's capacity. (Extract the most CO2 out of the atmosphere as possible over time)
2. Optimize volume and quality of durable wood products in harvestable trees. (Store the carbon as efficiently as possible in live trees)
3. Optimize ratio of byproduct utilization vs. waste. (Utilize as much of the harvested trees as practicable to extend carbon storage)

Note that in all cases, the extant stand conditions will determine what, if any, of these pathways will result in additional (and therefore marketable) carbon benefit. Advances in remote sensing that is sufficient to capture inventory change will be pivotal in determining the ease at which these management activities could be implemented and easily measured and monitored.

Forest Management Methods Included in SFLO Survey

1) **Afforestation** (create new forest land)
2) **Improved Forest Management (IFM)** (improve underperforming/unmanaged forest land)
3) **Extended Rotation (ER)** (increase timber/carbon sequestration over time per unit area)

4) **Legacy Forest Management (LFM)** (maximize carbon storage while harvesting excess)

Afforestation: create new forest land

Target Demographic: Landowners who have non-forested agricultural and ranching lands.

Pathway Goal: Convert under-utilized or unsuitable parcels (for crops or livestock) into forested landscapes appropriate for the site. Includes Silvopasture - integrating livestock foraging and forest development on the same parcel.

Additionality determination: Compare projected and realized tree growth to a zero (non-forested) baseline.

Examples of Existing Programs/Resource that could be implemented/adapted for Washington State:

USDA's Conservation Reserve Program (CRP) and other government cost-share programs have successfully implemented similar conservation objectives at a large scale for decades. These well-utilized programs could be further customized to emphasize carbon sequestration among other objectives. Currently, the CRP program has an incentive for Climate-Smart practices:
> *"Climate-Smart Practice Incentive: FSA provides an incentive of 3, 5, or 10 percent included in the annual rental payment for CRP practices that will increase carbon sequestration, reduce GHG emissions, and otherwise are climate smart practices. The incentive amount is based on the estimated benefits of each practice. "*

American Forest Foundation (AFF) Field to Forest (F2F) program - currently available in the state of Georgia: $30 per acre per year for 30 years to plant Loblolly pine in open space, usually on former agricultural fields. Additional income for the landowner is available via thinning and final harvest of the plantation:
> *"As the landowner of a new loblolly pine plantation, you will have the option to conduct one thinning and a final harvest. You keep the profits from these treatments. Should you choose to complete a final harvest, we will also pay for replanting another rotation of loblolly pine. Our pilot will also pay you $30 per enrolled acre per year for the 30-year landowner agreement."*

Improved Forest Management (IFM): improve underperforming/unmanaged forest land

Target Demographic: The vast majority of un-engaged SFLOs who are not actively managing their forestland or have no defined management objectives.

Pathway Goal: Develop management plans and implement site-specific practices to increase carbon sequestration alongside other management objectives.

Additionality determination: Compare projected and realized managed outcomes to a regional non-management or default baseline.

Examples of Existing Programs/Resource that could be implemented/adapted for Washington State:

AFF's Family Forest Carbon Program (FFCP) is specifically designed to serve this pathway. It incentivizes and guides inactive or otherwise interested forest landowners on a path to forest stewardship with measurable outcomes. Payments typically range from $10 to $20 per acre per year for a 20-year contract. FFCP needs to be customized for WA State forest types, and AFF has the experience and capacity to fully develop this pathway, with assistance from a regional partner organization.

Extended Rotation: increase timber/carbon sequestration over time per unit area

Target Demographic: Actively managing forest landowners who are growing and harvesting timber according to an economically optimal (short-term) rotation model. Could include industrial and other forest landowner categories beyond SFLOs.

Pathway Goal: Landowner commits to a specified extended period of tree growth before harvesting.

Additionality determination: Measure projected and realized timber growth beyond the "business as usual" rotation model.

Examples of Existing Programs/Resource that could be implemented/adapted for Washington State:

FiniteCarbon /CoreCarbon/ LandYield: Carbon-offset program in the voluntary market, verified by ACR, for small forest landowners with 40 to 5,000 acres. Landowners make a 40-year commitment including a harvest deferral for the first 20-year crediting period.

Port Blakely: Example of a timber company/forestland owner that has extended their harvest rotation to 60 years with financial support from the voluntary carbon market.

> *"In the Pacific Northwest, we found a forest for which we delayed harvest 20 years beyond standard practice carried about twice as much carbon as a typical industrial tree farm. This approach can help forestland owners overcome the barrier of the additional cost of managing forests to support habitat and conservation goals by monetizing the extra carbon – or additionality – being sequestered. The carbon credits produced by our 10,000-acre Winston Creek carbon project are being sold on the voluntary market. This allows us to continue to invest in this forest, supporting an ecosystem that will continue to sequester carbon every day for the next 40 years."*

Legacy Forest Management: maximize carbon storage while harvesting excess

Target Demographic: Actively managing forest landowners who have restricted harvest units or special sites like Riparian Management Zones (RMZs), steep and difficult-to-access parcels, etc. Could include industrial and other forest landowner categories beyond SFLOs.

Pathway Goal: Landowner commits to managing for continued optimum tree growth, with no planned replacement harvest. Thinning, salvage, and rehabilitation harvest may be implemented to achieve this goal.

Additionality determination: Measure projected and realized timber growth beyond the "business as usual" rotation model.

Examples of Existing Programs/Resource that could be adapted to address carbon benefit:

WA DNR: Forest Riparian Easement Program (FREP): 90% compensation for trees not harvestable due to regulations.

Proposed Programs/Resources:

Enhanced Forest Riparian Easement Program (EFREP) proposal: FREP with a carbon focus and active management of RMZs *(Literature: 003_EFREP Proposal.pdf)*

Two additional Forest Management Practices that we did not survey SFLO regarding their willingness to implement.

Wildfire Resilience: optimize durability of forest carbon in context with wildfire risk

Target Demographic: Forest landowners in fire-prone regions. Could include industrial and other forest landowner categories beyond SFLOs.

Pathway Goal: Develop management plans and implement site-specific practices to create a fire-resilient landscape with fuels reduction, appropriate tree stocking density and species mix.

Additionality determination: Calculate "durability" of managed forest carbon stocks due to reduced wildfire loss risk compared to the default baseline of non-management. Fewer and larger trees that can survive periodic wildfire achieve more carbon storage over time compared to smaller and more densely-packed trees with low ladder fuels that are far more likely to burn up and emit their stored carbon. Sometimes "less is more".

Existing Programs/Resources:

WA DNR's Forest Resilience Division: Financial Assistance Program for wildfire resilience and forest health
(Literature: 019_WA DNR grants for forest health restoration and wildfire resilience.pdf)

Federal: various agency programs: USFS and USDA funding for landowners; DOI and BLM funding for communities, tribes, and NGOs.
(Literature: 018_Wildfire_Resilience_Funding_TNC_ExecutiveSummary.pdf)

Urban & Community Forestry: IFM in the context of non-typical forested landscapes

Target Demographic: Residential landowners on small lots with a few trees up to a few acres. Land that has been converted from typical forest management but still has trees that could be managed for carbon. Also, for urban residents without land, opportunities for participation in carbon-focused practices on undeveloped marginal sites, parks and community forests.

Pathway Goal: Develop or improve existing programs to increase tree canopy coverage, with a carbon focus on long-lived, high value trees and rehabilitation of poor-quality sites.

Additionality determination: Many cities in Washington have programs to increase tree canopy coverage. For example, the City of Seattle estimated 18% coverage in 2017, with a 30- year goal to achieve 30% coverage. Additionality would be any increase above the current baseline of tree coverage (similar to Afforestation) and replacement of decadent or stagnant stands (similar to Improved Forest Management). This process could be applied to suburban and small rural landowners who fall below the size threshold for an SFLO.

Existing Programs/Resources:

City and Municipal funding: City of Seattle - Urban Forest Management Plan
(Image: 002_Seattle canopy cover goals - 2007 urban forest management plan.jpg)
(Literature: 002_Seattle Urban Forest Management Plan 2007.pdf)

Federal: USFS's Urban and Community Forestry (UCF) program.
(Literature: 020_USDA-2024-national-ucf-grant-program.pdf)

Appendix 6: Programmatic Decision Frames

Example decision frames for major elements needed to establish a workable carbon program for SFLO in Washington State. These include 1st, 2nd, 3rd and 4th level decision matrices that build on each other to ensure success and longevity of the carbon program.
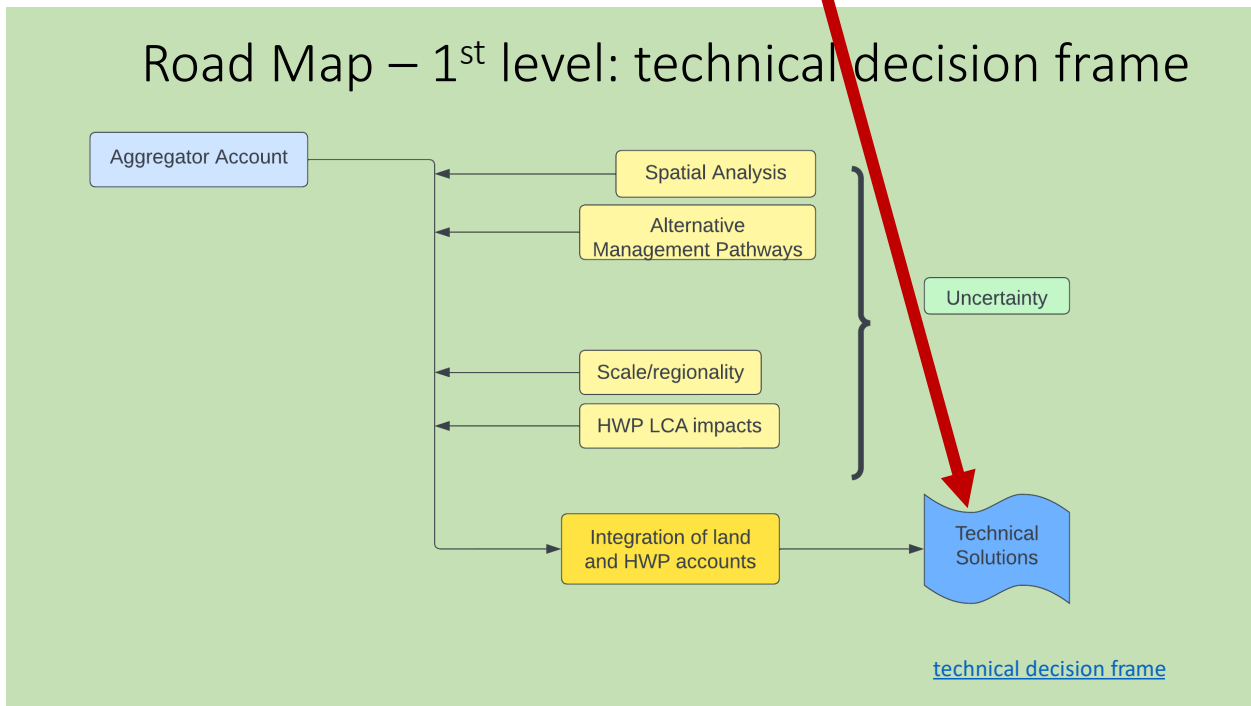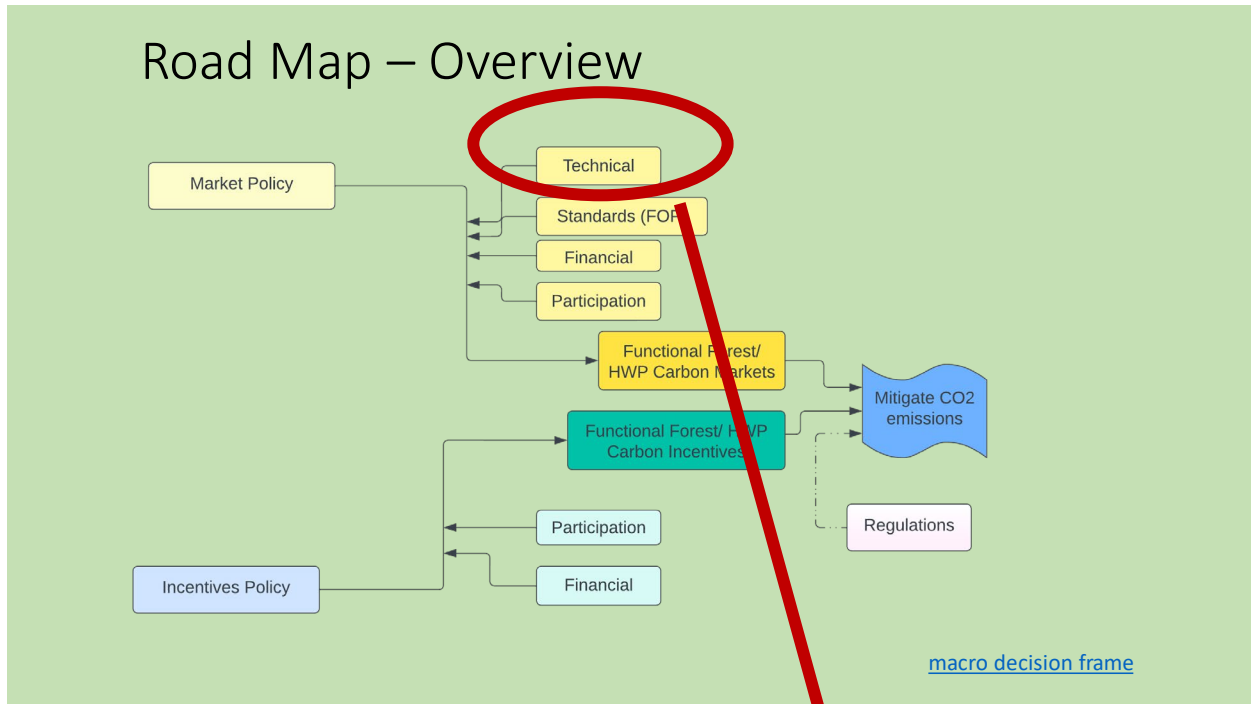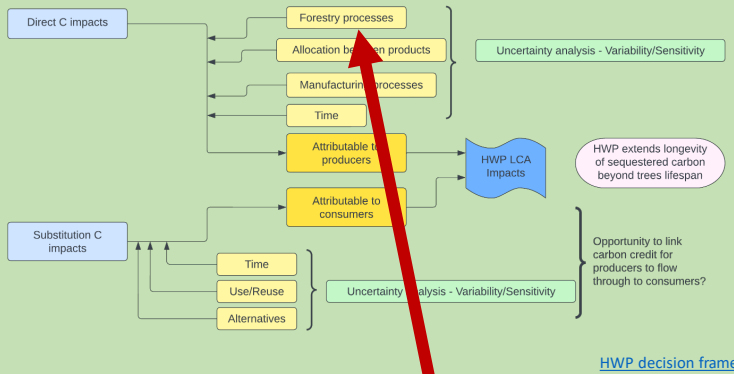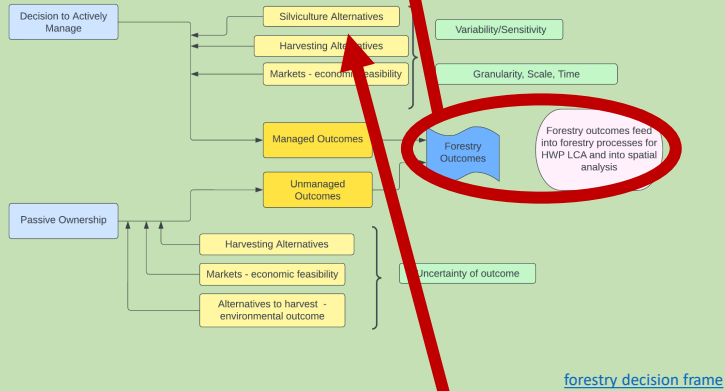

Figure 1: Example Decision Frame demonstrating the 1st and second level solutions needed to establish an aggregator account
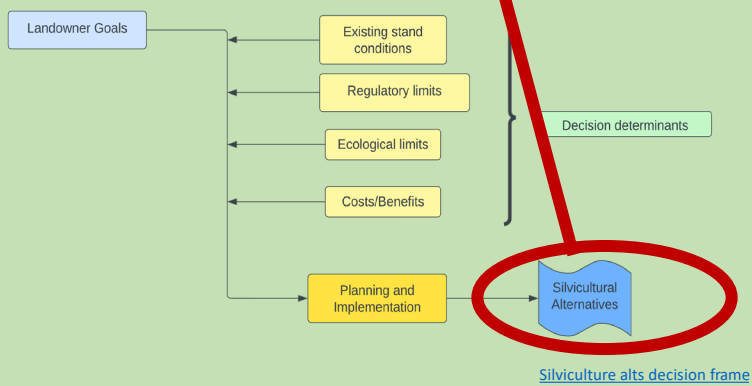
Figure 2: Decision Frame showing linkages between landowner goals, forestry outcomes, and HWP LCA
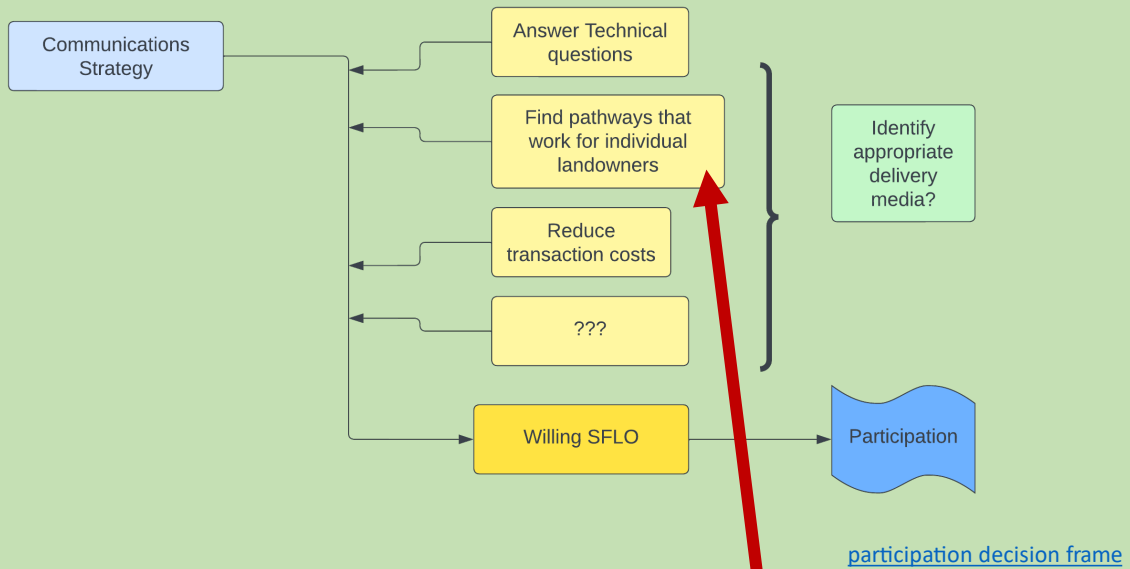
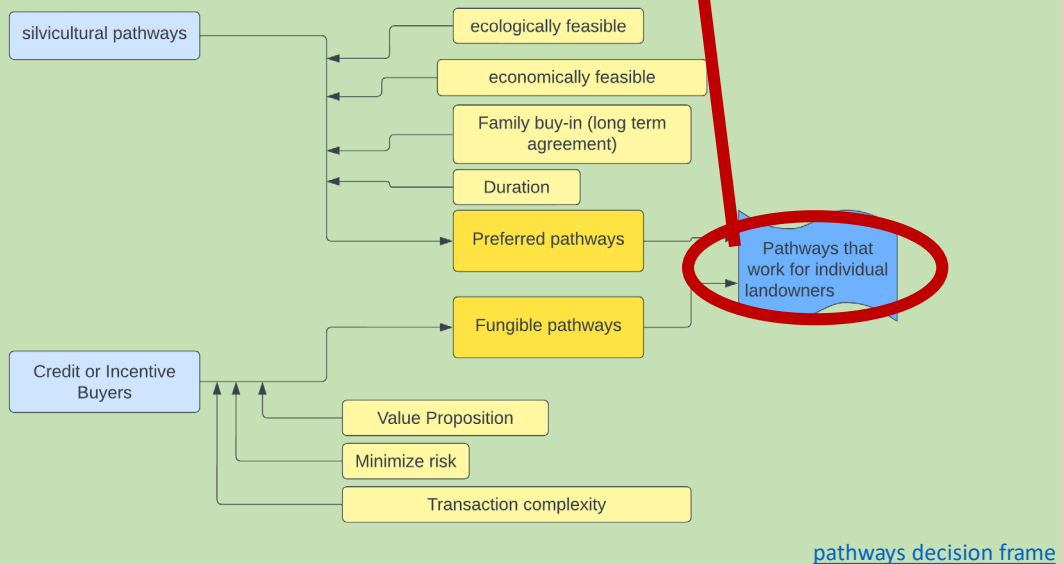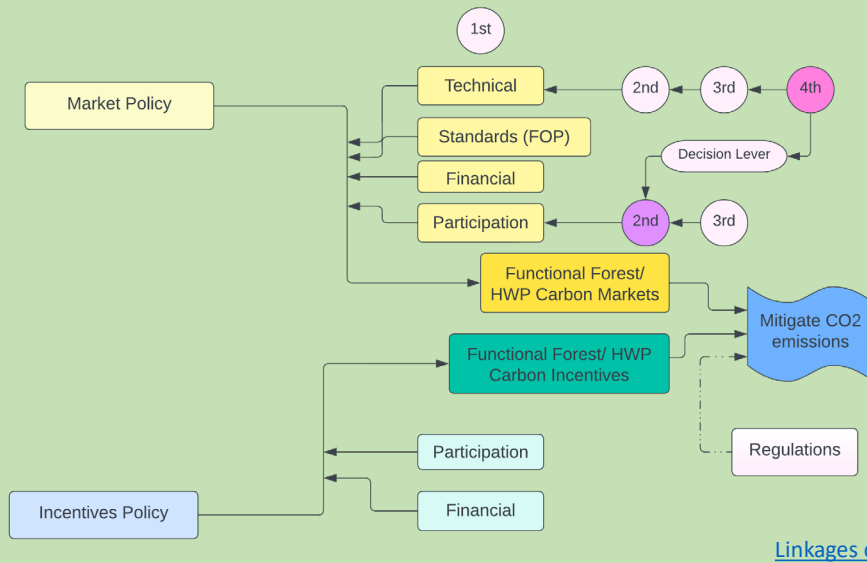*Figure 3: Decision Frame example for increased engagement.*

Figure 4: Linkages between and across programmatic elements demonstrate the need for a holistic approach to engaging SFLO in carbon market and carbon incentive programs.