Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Pacific Northwest Research Station | 2022 Carbon Research Initiative Update | December 2022

Pacific Northwest Research Station—Carbon Research Initiative Update, 2022

Glacier Peak Wilderness, Washington. Photo by Chelsea Kieffer.

Coproduction and the Research Framework

The U.S. Department of Agriculture (USDA), Forest Service, Pacific Northwest (PNW) Research Station's research framework was designed to ensure that the station's research is flexible, transparent, responsive, and relevant to partners. As a result, the research framework follows principles of "coproduction," in which station scientists work with key partners throughout the research cycle.

Within this framework, a "research initiative" is a strategically important line of research that is manageable in scope such that a team of scientists and partners can make demonstrable progress in 1 to 5 years. At the outset, a research initiative is a compelling issue that has been identified as a priority for key stakeholders. The research initiative is then developed via dialog involving partners and researchers who work together to identify and prioritize researchable questions, identify desired outcomes, and develop deliverables. The implementation of research is guided by a plan of work and supported by annual funding allocations from the PNW Research Station along with contributions from external partners or sponsors.

The Carbon Research Initiative: Background

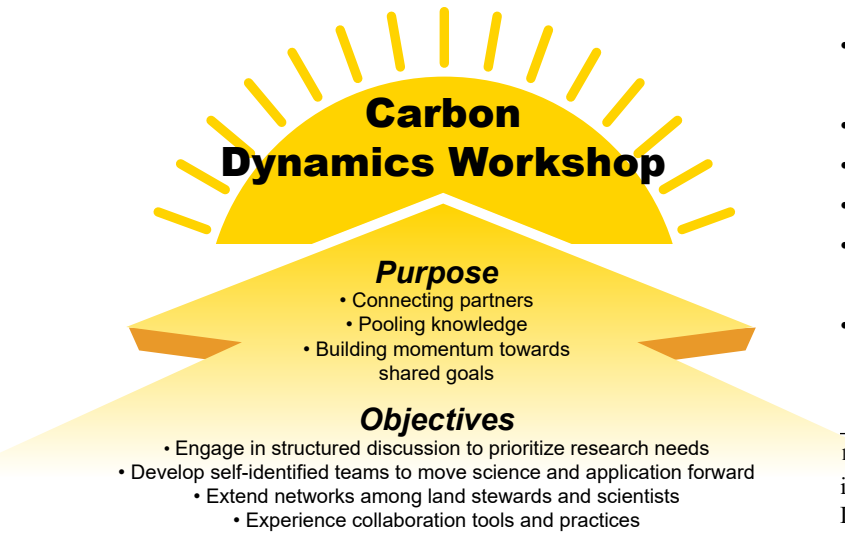
Human-caused greenhouse gas (GHG) emissions to the atmosphere are driving global climate change. The land sector is both a main source of emissions and a potential climate change solution. Globally, deforestation, unsustainable land management practices, and land degradation produce nearly a quarter of GHG emissions, and nature is currently the only mechanism we have to capture and store carbon at scale.

Conserving, managing, and restoring forests is a natural climate solution to address climate change by reducing GHG emissions, capturing and storing carbon dioxide from the atmosphere, and improving the health and resilience of ecosystems.

The overarching goal of the Carbon Research Initiative (hereafter Carbon Initiative), identified through dialog with land stewards, is to increase understanding of the tradeoffs and synergies between carbon and other values of interest (wood products, habitat, foods, water, etc.) and their effects on human economies and communities. In essence, the Carbon Initiative seeks to identify which forest stewardship practices and resource uses are most beneficial for countering carbon emissions.

This work is coproduced by PNW Research Station scientists and partners—initially Pacific coast state governments—with the goal of creating viable scenarios that can be used on the ground to sequester and store more carbon.

The Carbon Initiative began as a partnership to produce forest carbon status and flux reports on a regular basis to inform policies aimed toward carbon emissions reduction goals. Prompted by the newly created Pacific coast Memorandum of Understanding and the initial reporting of status and trends, the PNW Research Station hosted a workshop in 2019 to discuss carbon-related research needs. At that time, participants identified a handful of gaps in knowledge that grew into simultaneous, interactive projects where scientists and land stewards brought their respective skillsets together to investigate viable scenarios for improved carbon management.



Projects Contributing to the Carbon Initiative

Each project within the Carbon Initiative is linked in support of partner goals. Below we list the individual projects, their objectives, the progress made to date, the next steps for each project, the financial resources invested in the projects, a list of publications, and a list of partners for each project.

Carbon Science Synthesis Project

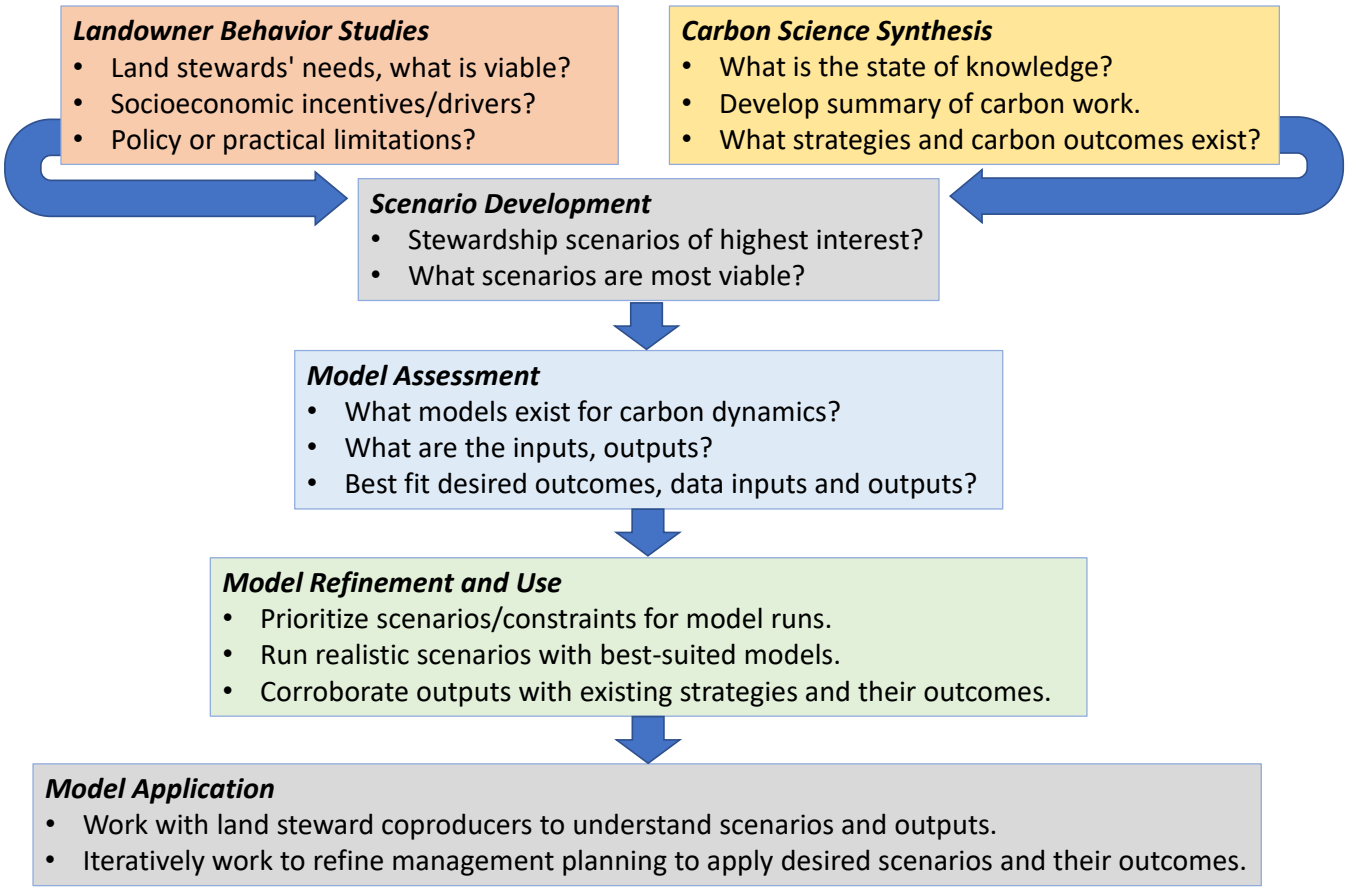
Objectives

- Help land stewards and others understand what is and is not known about managing forests, rangelands, and associated aquatic resources for carbon
- Identify critical gaps in knowledge about land management for carbon to develop a cohesive research agenda for Forest Service researchers and partners

Progress

- Wrote and published an article about the carbon pilot project in *Western Forester*
- Completed Zotero online shared library of carbon science synthesis literature[1]
- Created average soil carbon maps for 0 to 30 cm and 0 to 100 cm depths for the Pacific states
- Created soil carbon variation maps and data intensity maps
- Created Carbon Knowledge Synthesis Project website
- Extracting data from literature for all carbon pools
- Sharing Zotero library with interested parties (CAL FIRE, Washington State Department of Ecology)
- Developing story map/online tool to present soil maps online

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.



Carbon Initiative workflow. Landowner behavior studies and carbon science synthesis feed into scenario development. Then models are assessed and refined. Final models and results are communicated to land stewards and made available for management planning.

Next Steps

- Process large-scale data for the remaining carbon pools of interest and, where appropriate, produce manuscripts for these baseline data
- Continue to extract data from the literature to use in creating carbon pool response functions for a given silvicultural prescription or disturbance agent
- Create more material for online presentation via online story map or tool

Landowner Behavior Study

Objectives

- Evaluate the willingness of Pacific Northwest private forest owners (<5,000 acres) to adopt forest management strategies to enhance forest carbon stocks
- Evaluate the potential influence of alternative incentive structures and institutional arrangements on carbon-focused management strategy adoption
- Potentially use this information to inform and refine landowner behavior modeling

Progress

- Created a conceptual model of carbon and timber management under tax-financed investments in wildfire risk reduction
- Completed surveys and analysis of private forest owners (<5,000 acres) to identify factors influencing enrollment in preferential tax programs and how potential tax increases might influence forest management
- Developed a possible method to estimate stored carbon implications of changes in tax or other incentive levels

Next Steps

- Prepare Master's thesis, *Analysis of Oregon's Preferential Forest Property Tax Programs in Relation to Nonindustrial Private Forest Landowners' Program Enrollment and Forest Management Behavior*
- Prepare draft *Journal of Forestry* manuscript, "Carbon Storage Implications of Family Forest Owners' Responses to Property Tax Policies."
- Crossroads: about $50,000 remaining…

Fire and Carbon Oriented Management Across Pacific Northwest Forests

Objectives

- Identify the motivations and considerations that guide landowner and manager choices, including tradeoffs between managing for different goals
- Understand how Pacific Northwest forest landowners and managers address fire and climate change concerns through forest management
- Document the extent to which landscape-scale wildfire risk and fuels management is communicated and coordinated among different landowners
- Identify opportunities, policies, and programs to improve fuels and carbon management efforts
- Understand the social and economic feasibility of different fuels treatment activities and carbon management options, across a range of west-side landscapes and land ownerships
- Assess and compare modeled short- and long-term (40-year) outcomes under different management scenarios with respect to wildfire hazard, carbon stored in the forest and forest products, wood production, and economic returns relative to management costs

Progress

- Conducted 62 interviews with 65 people, spanning 60 federal, tribal, state, and private industrial ownerships to date
- Transcribed interviews and largely completed qualitative coding (using MAXQDA)
- Performing ongoing analysis
- Coordinating with BioSum modeling team to develop baseline and alternative management scenarios and associated prescriptions
- Drafting papers and other products (in early stages of development) that summarize our results

Next Steps

- Conduct additional private interviews where possible
- Continue ongoing analysis and coordination with BioSum modeling team
- Draft papers, presentations, and other materials that summarize results

A prescribed burn in the Colville National Forest, Washington. USDA Forest Service photo.

What is coproduction?

Coproduction means working hand in hand with partners through all phases of research, from defining problem statements, to outlining study plans, to delivering and integrating research findings and tools.

Only by bringing researchers and land managers together across geographic and institutional boundaries can we fully understand the decision-making context of our partners and and provide results in a way that they can apply them readily.

Beier, P.; Behar, D.; Helbrecht, L. 2015. How-to guide for the co-production of actionable science: how-to guide for DOI Climate Science Centers and the National Climate Change and Wildlife Science Center. Washington, DC: Advisory Committee on Climate Change and Natural Resource Science. DOI: 10.13140/RG.2.1.2830.0644.

Land Management Scenarios

Objectives

- Identify policies or regulations likely to be effective at reducing GHG emissions through shifting landowner behavior or incentivizing wood products production and use
- Prioritize alternative land management scenarios that are most feasible and of highest interest to our stakeholder community
- Understand and quantify the carbon sequestration implications of land management approaches and how likely forest landowners are to adopt them
- Identify ways that carbon management can be compatible with other nontimber objectives landowners might have

Progress

- Completed regional carbon report analysis
- Funded and completed Pacific coast timber flow analysis (University of Montana, Bureau of Business and Economic Research)
- Funded and completed Pacific coast wood products flow analysis (University of California, Berkeley)
- Completed CAL FIRE data visualization for Harvested Wood Products Carbon Model, available at: HWP Data Visualization (shinyapps.io)
- Preparing draft report, which establishes the 2019 business as usual (BAU) baseline scenario for forest and harvested wood product carbon stocks, carbon flux (as CO_2 sequestration/emissions by pool) and disturbance impacts throughout British Columbia, Washington, Oregon, and California
- Developing landscape management scenarios for California and Oregon through American Forests as separate agreements funded by CAL FIRE and Oregon Department of Forestry; specifically, completing analysis of California forest management and wood utilization carbon modeling (carbon budget model) (American Forests/Michigan State University), including the following:
  - Identifying the BAU baseline scenario
  - Developing scenarios (e.g., "resilience treatments," needs assessment)

Next Steps

- Revisit and confirm objectives and integration toward projection in management scenarios
- Decide how we move toward projections at a regional level, while evaluating progress toward state-level climate goals and evaluating other modeling approaches
- Incorporate ongoing research that considers regional impacts from disturbance, emerging carbon policy options, and changing landowner behaviors
- Move toward incorporating other states, regions, provinces, or collaboratives
- Identify a strategy for updates as new data and methods become available

Projecting Harvested Wood Products (HWP) and Substitution

Objectives

- Incorporate current harvest and manufacturing practices into estimates of HWP pools and flows
- Project future HWP pools and flows using removals projected from ecosystem models and potential changes in merchantability standards and future products
- Compare the carbon footprints of traditional and new wood products (e.g., mass timber in tall buildings) vs. common nonwood materials (e.g., construction with concrete or steel), their duration, and end uses to estimate potential substitution benefits

Progress

- Updated HWP accounting program, programmed HWP in R software, and published HWP online with programs and documentation
- Compiling an accounting of embodied GHG emissions and carbon stored for HWP pools from forests to end-of-life, including the following:
  - Preparing a life-cycle assessment (conventional and dynamic approaches)
  - Preparing a manuscript (near completion)
- Evaluating the effect of change in end-use product type, discard rates
  - Defining scenarios
- Conducting analysis of substitution benefits when HWPs displace nonwood products
  - Identifying match of functionally equivalent nonwood products that may be substituted by HWPs
  - Estimating the substitution factors for HWPs (i.e., kilograms of carbon emission saved by per kilogram of carbon in wood products substituting a nonwood product)

Next Steps

- Complete static and temporal tracking of HWP carbon pools for three PNW states
- Identify scenarios for future HWP pools with reduced GHG emissions or higher climate change mitigation potential

Expanding markets for engineered wood products generate the potential to sequester carbon for far longer than if this wood were burned, left to decay, or allocated to short-term uses like landscape chips or shipping pallets. Here, glulam columns support the cross-laminated timbers used to construct the Forest Center at Oregon State University. USDA Forest Service photo by Jeremy Fried.

Incorporating Forest Disturbance Into Forest Carbon Planning

Objectives

- Increase understanding about the relationship between disturbance, management, and carbon sequestration in Pacific coast states
- Address the following questions: (1) How do current models/methods incorporate disease, insect, drought, fire, and other disturbances? (2) Can incorporation of disturbances into planning for forest carbon sequestration be improved?

Progress

- Onboarded Oak Ridge Institute for Science and Education (ORISE) participant to help with project (11 July 2022 to 10 July 2023)

Next Steps

- Develop a draft report

Postfire timber harvest after the 2020 Archie Creek Fire, Oregon. Scientists are studying the relationships between disturbance, management, and carbon sequestration in Pacific Coast States. Photo by Cheyne Rossbach, USDI Bureau of Land Management.

Carbon Model Assessments and Improvements

Objectives

Models are needed to assess the potential effects of land management policies and practices on carbon stores in forests and rangelands, along with associated values and uses. Partners are asking for assistance in selecting models and scenarios to project the effects of alternative future management on ecosystem and harvested wood products. This project has the following key goals:

- Compare recently published modeling studies that quantify forest ecosystem carbon pools and fluxes in the region; assess approaches to predicting forest sector (ecosystem and HWP) pools and flux response to alternative management and climate change
- Apply a new dynamic global vegetation model to the region to simulate forest ecosystem carbon pools and fluxes into the future, incorporating interactions of climate change, ecosystem dynamics, stand dynamics, natural disturbance regimes, and management scenarios
- Provide recommendations to managers and policymakers on strengths and weaknesses of different modeling approaches and options for integration
- Provide estimates from regional forest inventories to help inform model development and application

Progress

- Hired a postdoctoral scholar through Oregon State University who has led the comparison of outputs by MC2, CLM, and LANDIS models against each other and against FIA and LEMMA (landscape ecology, modeling, mapping, and analysis) carbon estimates for a part of the Oregon Coast Range and for Malheur National Forest
- Postdoc facilitated regularly occurring meetings of the Carbon Initiative's modeling group to design assessments of models used to project forest ecosystem and harvested wood products, engaging with the PNW Research Station, Region 6, and non-Forest Service collaborators

- Developed growth and yield curves of carbon with stand age for west coast forests
- Compiled baselines of carbon stocks, disturbance, and management to inform scenario development and model comparisons
- Published paper on investigation of temporal stratification of forest inventories to improve accuracy
- Preparing a manuscript describing the results of model comparisons
- Completing synthesis of ecosystem and HWP models, and looking for faster alternatives for publication
- Preparing a paper on growth and yield curves of carbon with stand age for west coast forests

Next Steps

- Plan the application of ED2 to PNW area of interest
- Complete papers; work on presenting results, getting feedback, and devising recommendations for policymakers and managers

Improve Modeling of Belowground Carbon

Objectives

- Address uncertainties in soil carbon cycling specifically identified within soil carbon model frameworks
- Provide new interpretations and knowledge
- Coproduce science and promote collaboration across the northeast Pacific coastal temperate rainforest

Progress

- Two master's programs completed with manuscripts in review and preparation, one Ph.D. student in progress, and recruited two Ph.D. students with Fall 2022 start dates
- Preparing several manuscripts with two postdoc manuscripts in revision
- Completed nanoscale analyses with manuscripts in review and preparation
- Compiled substantial database of soil pedon data and soil sample archive for future work with new collaborators; soil information database contributes to the soil measurements for application in world-wide models
- Secured Environmental Molecular Sciences Laboratory user proposal to fund analyses and expertise contributed by Pacific Northwest National Laboratory scientists
- Deployed experimental weathering bags with retrieval in FY22, FY23, and FY24

Next Steps

- Develop primary outputs including journal manuscripts, conference presentations, proceedings, and project reports

Soil layers in a spruce forest. Tremendous amounts of carbon are stored below ground in soil.

Resources

Pacific Northwest Research Station, USDA Forest Service

Project	Current spending			
	FY20	FY21	FY22	Total (all years)
	U.S. dollars			
Science Synthesis	39,611	121,693	129,444	290,748
Socioeconomics/Landowners	100,000			100,000
Forest Disturbance	100,000			100,000
Management Scenarios	79,048			79,048
Model Assessments	185,000			185,000
Harvested Wood Products	150,000			
Improve Belowground Carbon	143,492			237,491
Model Improvements and Assessments		100,000	199,993	299,993
Total	797,151	221,693	423,436	1,442,280

Investments to Cooperators

Cooperator	Amount	Project	Outcomes
Landowner Behavior Study			
Oregon State University	$100,000	Socioeconomic incentives and drivers of carbon management	Developed, deployed, and analyzed a survey of small forest landowner perceptions and participation in state-level programs. Used survey data with FIA to build policy scenarios.
Land Management Scenarios			
University of Montana	$30,000	Pacific coast regional wood flow analysis	Quantified timber imports, exports, and regional interstate transfers. BC, CA, OR, and WA completed and report submitted to PNW.
UC Berkeley	$49,048	Analysis and survey of wood product flows within Pacific coast region	Identified, compiled, and analyzed all public sources of wood product trade flow. Report submitted to PNW.
Projecting Harvested Wood Products and Substitution			
ORISE	$150,000	ORISE fellow	Compiling an accounting for embodied GHG emissions and carbon stored for HWP pools from forests to end-of-life. Preparing life cycle assessment.
Incorporating Forest Disturbance Into Forest Carbon Planning			
ORISE	$100,000	ORISE ecologist—disturbance and carbon	Improving methods used to understand storage and flux of carbon in the Pacific west, particularly in relation to disturbance (fire, insects, disease).

Cooperator	Amount	Project	Outcomes
Carbon Model Assessments and Improvements			
ORISE	$185,000	ORISE carbon analyst	Identifying key issues and tradeoffs faced by managers and policymakers in managing carbon stores on diverse forested landscapes.
Oregon State University	$100,000	Continuation of development of the next generation dynamic vegetation model for the Pacific Northwest	Compared outputs by MC2, CLM, and LANDIS against each other and against FIA and LEMMA-based carbon estimates for a part of the OR Coast Range and for Malheur NF. Manuscript pending.
Oregon State University	$39,993	Application of fire and vegetation models for the Pacific Northwest and the globe	Joint effort will apply ED2 dynamic vegetation model and FSim fire model to Oregon and Washington and apply MC2 to the globe.
ORISE	$160,000	Research fellow in dynamic vegetation modeling	Seeking ways to advance the science of dynamic global vegetation modeling (DGVM) by applying a next generation DGVM to the Pacific Northwest at a fine spatial scale.
Improve Modeling of Belowground Carbon			
Oregon State University	$78,492	Soil carbon stabilization through physical, chemical, and biological weathering along the Pacific coastal margin	Performing density separations on archived samples to understand carbon distribution and partitioning along the lithosequence.
University of Washington	$30,000	Carbon storage and flux in forested wetlands across the north Pacific coastal temperate rainforest	Establishing field sampling protocols for belowground carbon in wetland dominated landscapes.
University of Alaska	$50,000	Carbon storage and flux in forested wetlands across the north Pacific coastal temperate rainforest	Sampling rock and soils and subsequently providing advanced analytical tools to elucidate soil development in the coastal temperate rainforest of southeast Alaska.
University of California, Davis	$43,999	Incipient weathering for nutrient cycling and carbon sequestration in forests of the Pacific coastal margin	Sampling soils and examining how soil formation is related to rock weathering of ecosystems ranging from the coast redwoods in California to the perhumid coastal rainforest region of Alaska.
University of Alaska, Southwest	$35,000	Hydrologic controls on watershed biogeochemistry	Measured discharge measurements from core hydrologic sites to update/develop streamflow rating curves. Provided data and information to carbon flux and fate project and to larger Alaska/British Columbia hydrology modeling project.

Partner Investments and Related Work

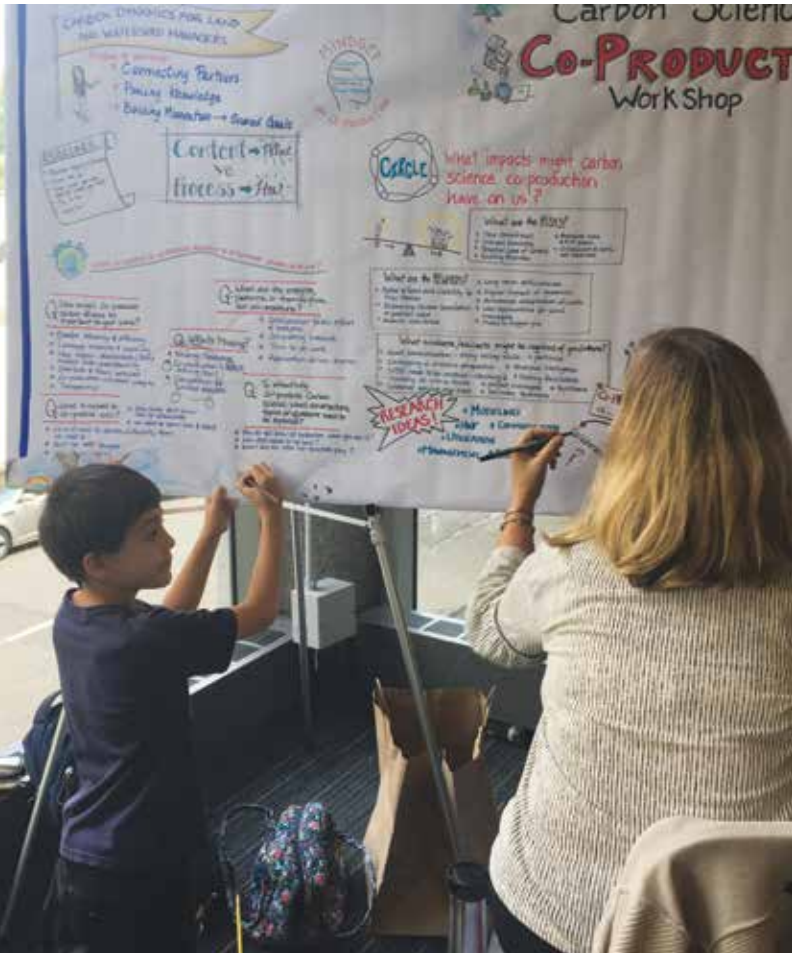
Investor	Recipient	Amount	Project
CAL FIRE	American Forests	$260,948	Scenario development toward modeling…
Oregon Department of Forestry	American Forests	$130,000	Scenario development toward modeling…
CAL FIRE	PNW Research Station	$154,050	Pacific coast temperate forest carbon report
CAL FIRE	Groom Analytics	$58,125	Programming and development of Harvested Wood Products Carbon Model, California, V. R
Oregon Department of Forestry	Groom Analytics	$43,250	Programming and development of Harvested Wood Products Carbon Model, Oregon, V. R
CAL FIRE	UC Berkeley	$44,126	Economic analysis for CBM-CFS3 carbon modeling with American Forests

Conclusions

These investments have strengthened relationships, synthesized knowledge, and refined modeling approaches. The results are being shared through a number of publications, presentations, and websites.

One of the most successful outcomes of the Carbon Initiative to date has been the increased partnership work communicating results that make a real difference on the ground. Via the partnerships, we have identified some challenges and many opportunities that lie ahead, which include the following:

- Scenarios are incredibly difficult to develop and require a slew of assumptions to prepare them for modeling carbon outcomes into the future.
- Carbon models are all very different in their inputs, outputs, assumptions, geographic scope, and processing requirements.
- Our own expertise in modeling is limited and requires us to extend our partnerships to bring in additional talent.
- Using additional modeling talent to work with other modelers toward a comparative approach will require serious coordination, project management, and leadership insight to agree upon desired outcomes.
- The coproduction model of research where land stewards work with researchers on an ongoing basis is new for many of the individuals involved in the initiative and will take time to cultivate.
- As we move from business-as-usual modeling scenarios to the incorporation of desired outcomes for landowners and land stewards, we expect a larger range of modeling efforts with new partners to evolve.



Graphic artists capture the process of coproduction at the 2019 Carbon Initiative Workshop. USDA Forest Service photo by Jane Terzibashian.

- As we incorporate climate and disturbance change analyses into scenario development, we expect additional complexity coupled with greater reliability in the carbon sequestration and flux projection outputs from the models
- We plan to host another carbon workshop in late 2023 to align our carbon projects, discuss results, and plan for additional needs and changes in directions
- We plan to host a "Results Reveal" for the Carbon Initiative for a larger PNW audience in 2024

The Carbon Initiative has been a successful experiment overall. We have joined forces through the course of the research cycle to work toward delivering usable carbon science for land stewards and policymakers. The initiative has spurred additional projects sponsored by partners that are taking the work further than originally envisioned and providing new insights and science delivery mechanisms to enhance the overall objectives

Publications Completed/Submitted

D'Amore, D.V. 2020. An overview of the belowground carbon cycle. Western Forester. 65: 4–6.

Jones, D.; Gray, A.; Lucey, T. 2020. Navigating carbon science and research underway in the greater Pacific Northwest. Western Forester. October/November/December: 13–15.

Fedenko, J. 2021. Soil development and organic carbon persistence across a lithosequence in the perhumid coastal temperate rainforest of southeast Alaska. Oregon State University. M.S. thesis.

Fleiner, J. 2021. Lithologic controls on soil carbon partitioning in the Alaskan coastal temperate rainforest. Oregon State University. M.S. thesis.

Rue-Johns, A.Z.; Crotteau, J.S.; D'Amore, D.V.; Barnard, J.C. 2021. Biomass regressions for understory species in young-growth Sitka spruce-western hemlock forests of southeast Alaska. Northwest Science. 95: 114–124. https://www.fs.usda.gov/research/treesearch/63963.

Rushakoff, B. 2021. An analysis of Oregon's preferential forest property tax programs in relation to non-industrial private forest landowners' tax program enrollment decisions and forest management behavior. Oregon State University. 169 p. M.S. thesis.

Behnke, M.I.; Fellman, J.B.; D'Amore, D.V.; Gomez, S.M.; Spencer, R.G.M. 2022. From canopy to consumer: what makes and modifies terrestrial DOM in a temperate forest. Biogeochemistry. 51: 4328–4349. https://www.fs.usda.gov/research/treesearch/65430.

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Mauro F.; Monleon VJ.; Gray AN.; Kuegler O.; Temesgen H.; Hudak AT.; Fekety PA.; Yang Z. 2022. Comparison of model-assisted endogenous poststratification methods for estimation of above-ground biomass change in Oregon, USA. Remote Sensing. 14(23): 6024. https://doi.org/10.3390/rs14236024.

Spinola, D.; Portes, R.; Fedenko, J.; Lybrand, R.; Dere, A.; Biles, F.; Trainor, T.; D'Amore, D.V. 2022. Lithological controls on soil geochemistry and clay mineralogy across Spodosols in the coastal temperate rainforest of southeast Alaska. Geoderma. https://doi.org/10.1016/j.geoderma.2022.116211.

Rushakoff, B.; Kuusela, O.; Cushing, T.; Kline, J.D. In review. Carbon storage implications of family forest owners' responses to property tax policies. Journal of Forestry.

Publications in Preparation

Charnley, S. Fire and carbon-oriented management across Pacific Northwest forests: large landowner perspectives and practices.

Chisholm, P.; Gray, A. Forest carbon sequestration on the west coast, USA: role of species, productivity, and stockability.

Christensen, G.; Tase, N.; Gray, A.; Kuegler, O.; Drummond, J.; Dymond, C.; Kurz, W.; Morgan, T.; Thale, D.; Evans, S.; Scott, S. Pacific coast region temperate forest carbon dynamics: 2001–2019; a regional forest carbon assessment of British Columbia, California, Oregon, and Washington.

D'Amore, D. Nanoscale analyses for modeling belowground carbon.

Dillon, T.; Morgan, T. Pacific coast temperate forest timber product flow. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Evans, S.; Potts, M. The flow of primary wood products in the Pacific coast region.

Gray, A.; Lucey, T.; Kim, J.; D'Amore, D.; Yost. A. Forest ecosystem carbon models: a synthesis of applications to current issues on the west coast.

Jones, D.; D'Amore, D. Soil organic carbon ensemble model for ecoregions in the Pacific region of North America and Hawai'i.

Khatri, P.; Nepal, P.; Sahoo, K.; Bergman, R.; Nicholls, D. Dynamic accounting of embodied carbon of harvested wood products in California.

Kim, J. Comparison of simulated future carbon projections in the Pacific Northwest.

Lucey, T.; Tase, N.; Prakash, N.; Bergman, R.; Nicholls, D.; Khatri, P.; Sahoo K.; Gray, A. Harvested wood product carbon model synthesis.

Stewart, A.; Butman, D.; Moskal, M.; Halabisky, M.; D'Amore, D. A framework for quantifying carbon export from range and forested watersheds.

Carbon Initiative Websites

Pacific Northwest Research Station, USDA Forest Service

Carbon Dynamics Research for Land and Watershed Managers

Carbon Model Assessments and Improvements

Fire and Carbon-Oriented Management Across Pacific Northwest Forests

Carbon Science Synthesis Project

CAL FIRE

Forest Carbon Monitoring and Research

Harvested Wood Products Carbon Model

Project Participants (leads in bold)

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Improve Modeling of Belowground Carbon

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