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Sustainable Biomass Through Forest Restoration

DOE Bioenergy Technologies Office (BETO) 2023 Project Peer Review

April 02, 2023

Data Modeling and Analysis

Principle Investigator

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Pacific Northwest National Laboratory

PNW

Project Overview

- In 2022, ~69,000 wildfires burnt over 7.5 million acres with six fires each requiring over $90,000,000 dollars in suppression cost alone. Climate change, fire exclusion, increased forest density over the last century, and an insufficient fuel reduction footprint contributed to the severity of the wildfires.
- Fuel reduction activities including commercial and pre-commercial thinning can generate significant quantities of residue that may be collected and used for bioenergy or bio-based products. There is potential to leverage these investments to achieve:
  - Increased public health and safety through a marked reduction in
    - The intensity of wildfire and smoke emissions
    - Smoke associated with prescribed burning for post-harvest slash disposal
  - Concurrent hydrologic benefits – increased streamflow and improved timing with associated benefits to native fish
  - Economic and societal benefits through job creation and collection of residues for bioenergy

This project is using a linked set of spatial, biophysical models coupled with existing EMDS decision support software to demonstrate an analysis framework to prioritize how and where to target forest restoration to address multiple objectives.

Task Coordination

- Project Communications
  - Weekly planning with PNNL staff
  - PNNL/USFS conference calls as needed
  - USFS subcontract reporting
  - Quarterly calls with BETO Analysis and Sustainability
  - Regular outreach to collaborators and stakeholders:
    - WA Department of Natural Resources
    - Washington Water Trust / Colville Confederated Tribes
    - USDOE Waterpower Technologies Office
    - Blue Forest
    - University of Nevada Reno
- Project Risk
  - Potential delays associated with USFS funding through an Interagency Agreement (IAA)
  - Lack of certain data or inputs

PI/PM Wigmosta (PNNL)
PI Paul Hessburg (USFS)
CO-I Tucker Furniss (USFS)
CO-I Zhuoran Duan (PNNL)

Task	Lead
Task 1: Expand Study Domain to Methow and Okanagan	Tucker/Duan
Task 2: Simulation of vegetation regrowth to better estimate long-term biomass supply and impacts to wildfire intensity and streamflow	Tucker/Duan
Task 3: Impacts of Climate Change, Forest Restoration, and Wildfire on Snowpack and Streamflow	Duan/Tucker
Task 4: Project Peer Review, Technology Transfer, and Outreach	Wigmosta/Hessburg

1 – Approach:

Forest Restoration Scenarios to Restore the Landscape to a Pattern more Consistent with the Native Fire Regime

- 100 to 170 years of fire exclusion and forest densification has led to increased tree cover and associated surface and canopy fuels
- **Goal:** Adapt forested landscapes to a pattern that is attuned to shifting wildfire and climatic regimes
  - More frequent, less intense wildfire
  - Heterogenous mosaics of variably sized clumps and canopy gaps

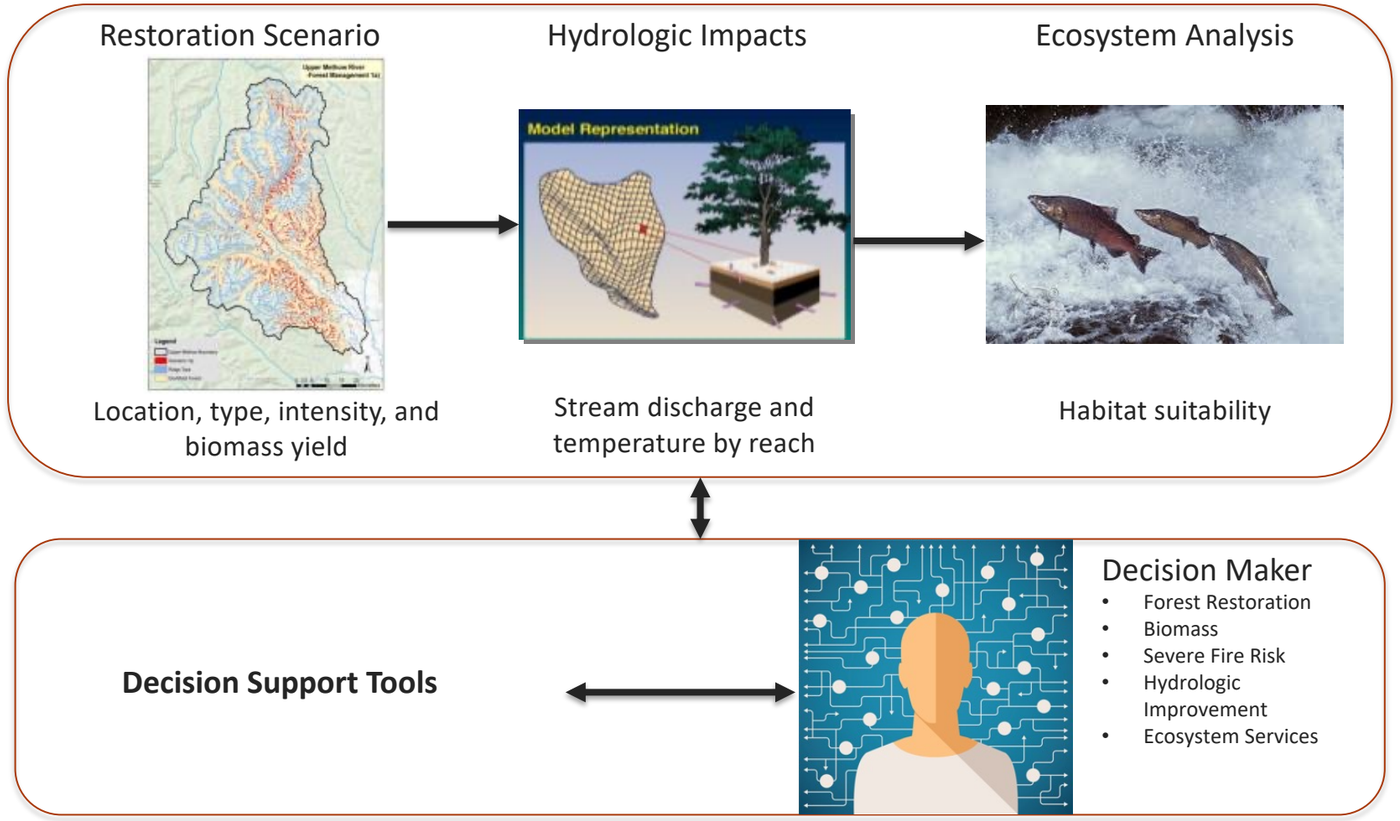
Major Assumptions

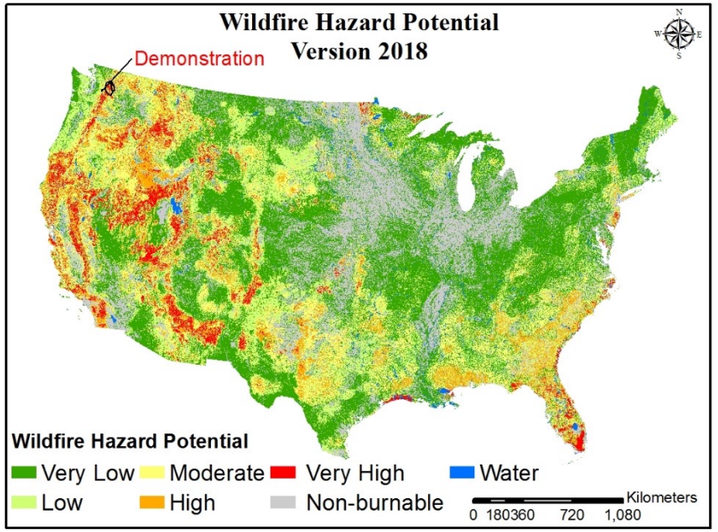
- Restoration through:
  - Commercial thinning + prescribed burning
  - Prescribed burning and managed wildfire in backcountry locations
- Only consider biomass for energy associated with commercial activities
  - No monetary or regulatory incentives

(From WDFW Thinning treatments at Sinlahekin Wildlife Refuge

1 – Approach:

Integrate Detailed Spatiotemporal Data with Biophysical Models for Multi-Scale Tradeoff Analysis





EMDS is the USFS corporate software solution for decision support and has been used by the USFS and Bureaus of the Department of the Interior (USDI) since 2006 to evaluate wildfire potential across all administrative units in the continental United States, and to establish priorities for allocating fuel-treatment budgets.

Initial focus on high-risk areas in the Pacific Northwest at watershed to regional scale using data, models, and analysis techniques that can be applied nationally

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1 – Approach:

Incremental Treatment, Wildfires, and Dynamic Vegetation over the 21st century

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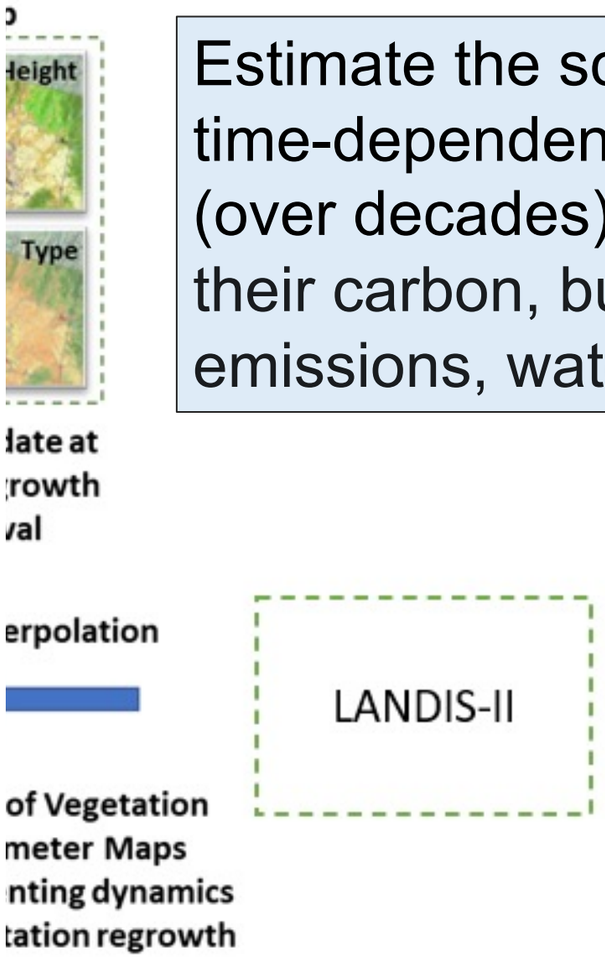


Estimate the scale of spatially explicit, time-dependent forest treatments required (over decades) to stabilize landscapes, their carbon, burned area, smoke emissions, water resources, and biomass

- LANDIS-II simulates forests (both trees and shrubs) at decadal to multi-centenary temporal and spatial scales spanning thousands to millions of hectares.
- The model simulates change as a function of growth and succession as they are influenced by a range of disturbances (e.g., wildfire, wind, insects), forest management, land use, and climate change.

2 – Progress and Outcomes

100-Year Simulations in the Wenatchee Watershed

Scenarios

- ***Grow out*** –Estimates vegetation growth absent active management
- ***Wildfire only*** – Simulates vegetation growth + wildfire for 100 yrs
- ***Wildfire + Rx fire –*** Simulates growth, wildfire + Rx fire for 100 yrs
- ***Wildfire + Rx fire + WFU –*** Simulates growth, wildfire, Rx fire, and wildland fire use in wilderness areas for 100 yrs
- ***Wildfire + Harvest*** – Same as *Wildfire only* but with thinning treatments applied in actively managed forests for 100 yrs
- ***Wildfire + Rx fire + Harvest –*** Same as *Wildfire + Rx fire* but with thinning treatments applied in actively managed forests for 100 yrs.
- ***Wildfire + Rx fire + WFU + Harvest –*** Same as *Wildfire + Rx fire + WFU* but with thinning treatments applied in actively managed forests for 100 yrs

COHESIVE RESILIENCE

Economic viability

Community needs

Ecological functioning

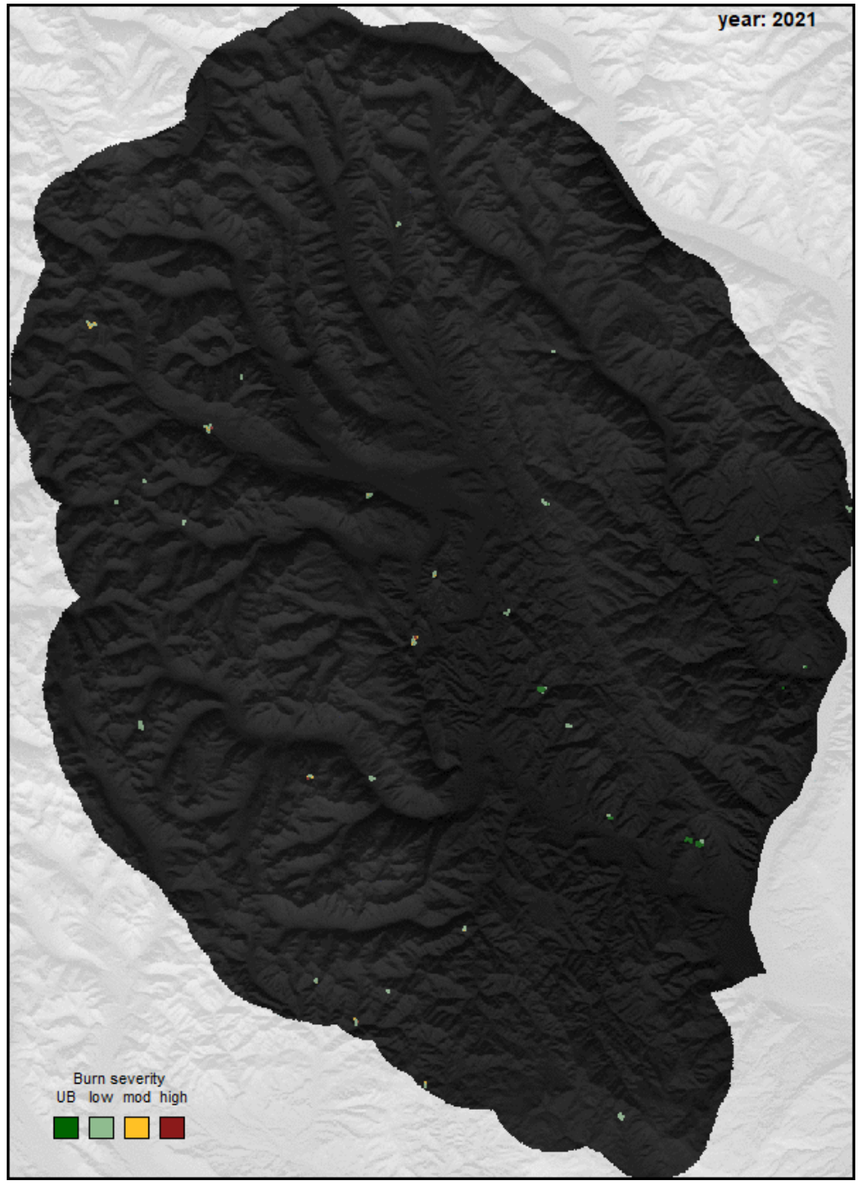
Topic	Economics	Sustainable biomass	Carbon	Water	Wildfire	Forest health and resilience	Landscap integrit
Concepts of interest	*Cost of management actions*	*Sustainable biomass production and fuel reduction*	*Carbon stocks and sequestration*	*Streamflow and snowpack*	*Good fire, bad fire, and community impacts*	*Quality of forest stands and climate adaptation*	*Pattern and conversio*

Element	Revenue	Timber harvest	Carbon pools	Streamflow	Fire activity	Forest health	Heterogen
Metric	Merchantable timber revenue ($/year)	Merchantable timber (Mg/year)	Aboveground live C (Mg C)	Melt out date	Average severity (pseud-dNBR)	Percent mature forest area (>50 years old)	Distance t nearest see source (m
	Chip revenue ($/year)	Chip / pulp biomass (Mg/year)	Aboveground dead C (Mg C)	Mean annual flow (m)	High severity burn area (ha)	Area of old forest patches (>10 ha)	HUC12-lev structura diversity
		Area treated (Ha/year)	Soil carbon (Mg C)		Low severity burn area (ha)	Old Forest (>120 years old; binary)	HUC12-lev compositio diversity
			Belowground live C (Mg C)		Rx fire burn area (ha)		Distance to forest (m
			Belowground dead C (Mg C)		Area burned in WUI (Ha)		

Element	Costs	Sustainability	Carbon fluxes	Snowpack	Smoke emiss.	Resilience	Type char
Metric	Rx fire op. cost ($/year)	Delta biomass since start year	Net Ecosystem Exchange (Mg C/year)	Peak SWE (cm H20/m2)	Pm 2.5 (Mg C)	Drought susceptible biomass (Mg)	Persistence initial cover t (binary)
	Timber operations cost ($/year)		Net Primary Productivity (Mg C/year)	Peak SWE date (Julian day)	Pm 10 (Mg C)	Area of homogeneous age and cover type (ha)	Type convers (forest gain/l 1 to 1)
	Suppression cost ($/year)				Timing of smoke emissions (percentile)		

100-Year LANDIS-II Simulated Wildfire

- Need to consider wildfire in planning decisions
- Wildfire currently “treats” more acreage than forest restoration. In 2022
  - 68,988 reported wildfires
  - 7,577,183 acres
  - 2,717 structures
  - 6 fires with estimated suppression costs of over $90,000,000 each

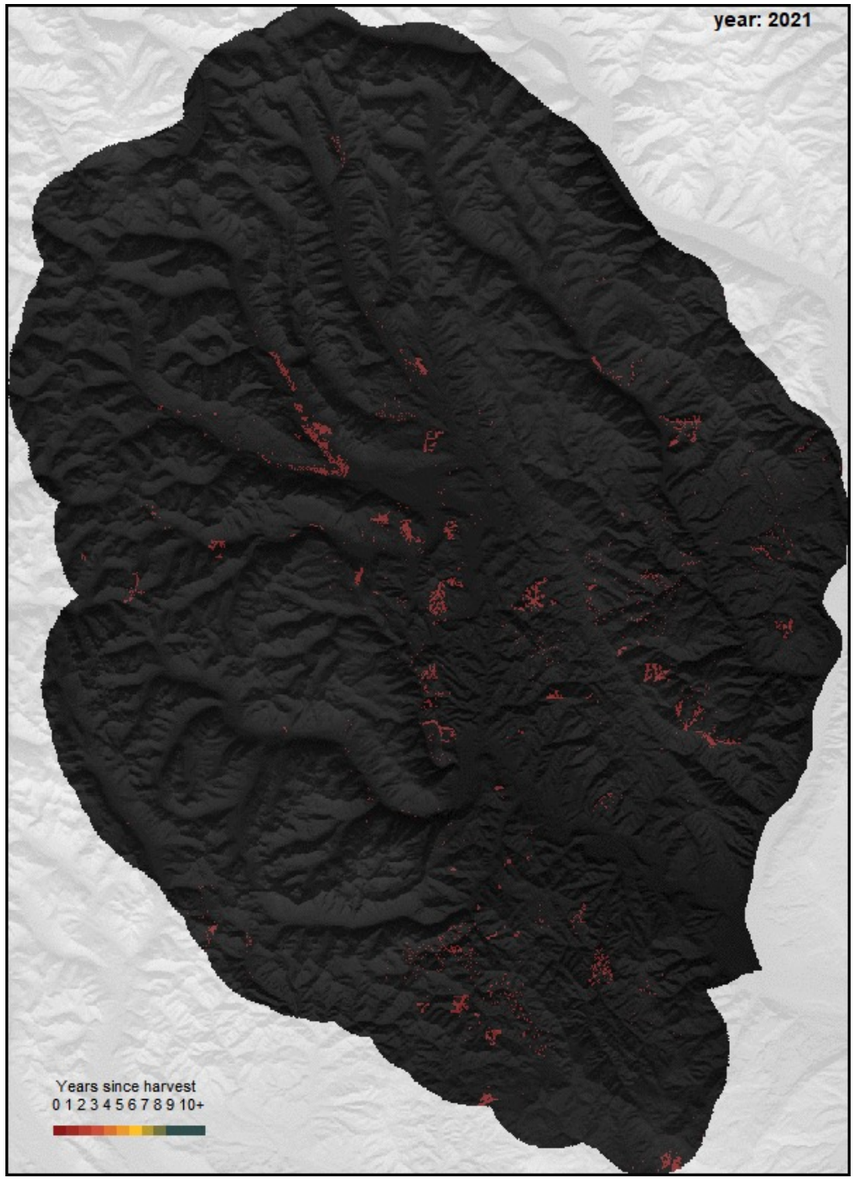


Fire

- Wildfire
- Weather, topography, and fuels drive fire spread
- Spatially variable suppression
- Rx fire

100-Year LANDIS-II Simulated Timber Harvest

- We assume biomass for energy is associated with commercial harvest
- To reflect reality, harvest takes place over time

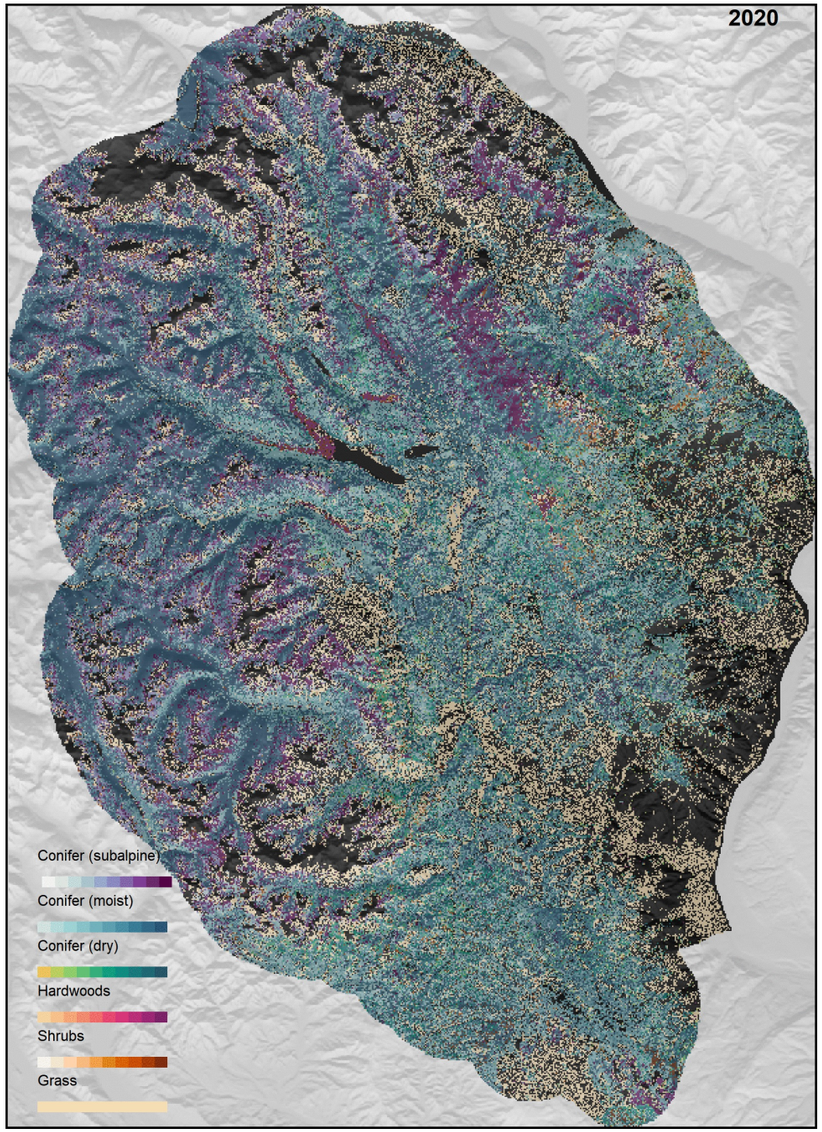


Timber harvest

- Sustainable rates
- Spatially allocated by stand
- Restoration-focused Rx
- Multiple prescription types
- 100-year treatment window

100-Year LANDIS-II Simulated Biomass Dynamics

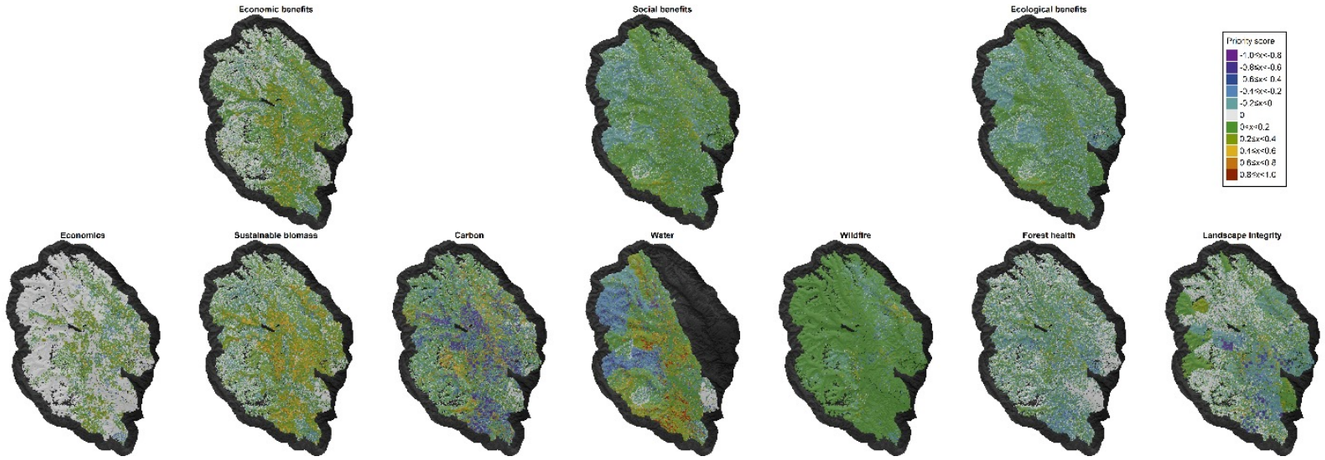
- It is critical to consider vegetation grow and regrowth after treatment
  - Impact on ecological services
  - Required maintenance to maintained reduced risk of wildfire
  - Sustainable biomass supply



Ecological succession

- Growth
- Competition
- Mortality
- Dispersal

Preliminary Results: Strong Support for the Harvest Scenarios among both Economic Viability and Community Needs Primary Topic Areas



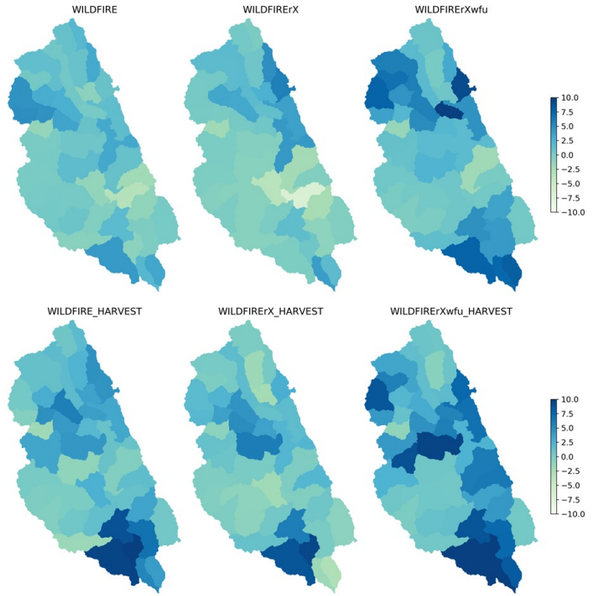
There was strong support for the *Harvest* scenarios among both Economic Viability and Community Needs primary topic areas

- Driven primarily by the production of merchantable biomass which produced benefits among both categories, along with the reduction of forest density which produced increased streamflow and snowpack retention, which was an important driver of the Community Needs topic area.
- Benefits were rooted primarily in actively managed forests but did extend into forests surrounding these treated patches. These concomitant benefits for the surrounding forest area, most notably among the water and wildfire topic areas, demonstrate the potential for treatments to reduce fire frequency and fire risk in forests adjacent to the treated areas as well.

Preliminary Results: Mechanical Harvest Improved Snowpack Retention and Increased Streamflows

Snowpack and Streamflows

- Mechanical harvest improved snowpack retention and increased streamflows relative to the Wildfire Only scenarios.
- While individual wildfire events enhanced streamflow by reducing stand density, these effects were smaller in magnitude and were not distinct enough between scenarios to produce a notable result.
- The effect of location-specific treatments on streamflows may persist for decades after treatments stopped.



Annual flow change (%) compared to “Grow out” scenario

Note:

- In the 1855 treaty with the Yakama, 14 bands and tribes ceded 11.5 million acres to the United States. Today, representatives of each of those bands and tribes make up the Yakama Tribal Council. The tribe, which uses an interdisciplinary and sustainable approach to care for the land and natural resources, operates a fisheries program.
- The Yakama Indian Nation co-manages the Columbia, Wind, White Salmon, Klickitat, Yakima, ***Wenatchee, Methow, Entiat, and Okanogan rivers***.
- We are ramping up efforts to work with the tribes to apply our tools and to seek NSF funding for a large, 10 year, restoration and economic development grant, last slide.

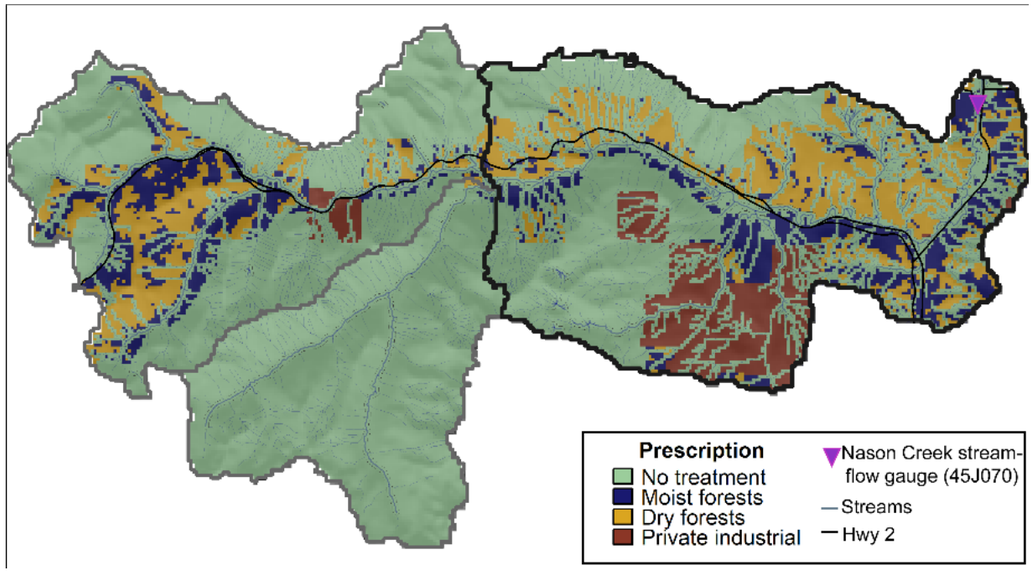
Follow on Funding: Technology Transfer through Industrial Partnership

2023-2025: **RESTORE: Replenishing EcoSystems by Transforming Residues to Energy,** funded by BETO Scale Up for Accelerating Domestic Biofuel Production

- Led by LanzaTech, pilot an integrated field-deployable, zero-discharge, biorefinery concept for distributed production of ethanol – as feedstock for larger LanzaTech alcohol-to-jet SAF facilities – and biochar for soil amendment.
- One target application is processing residues and small-bore trees removed by the US Forest Service (USFS) to reduce wildfire risk.
- Pacific Northwest National Laboratory (PNNL) and the USDA-FS, PNW Research Station will assess ecosystem services impacts at the watershed level and Roundtable on Sustainable Biomaterials (RSB) will advise on requirements for sustainability certification.

3 – Impact

Follow on Funding: Supporting Multi-Objective Forest Management in Washington State



2022-2023: **Landscape Management Simulator (2023) / Modeling Landscape Scale Treatment Effects on Snowpack and Streamflow (2022),** Washington State Department of Natural Resources

- Demonstrate the use of process-based landscape dynamics models to simulate wildfire, silvicultural treatments, snow dynamics, and hydrologic output over the next 20 years in several of the priority planning areas identified under the WA DNR's 20-Year Forest Health Strategic Plan for Eastern Washington.
- Federal, State, and Private land

Follow on Funding: Supporting Multi-Objective Forest Management in Northern California

Tahoe Central Sierra Initiative (TCSI) territory

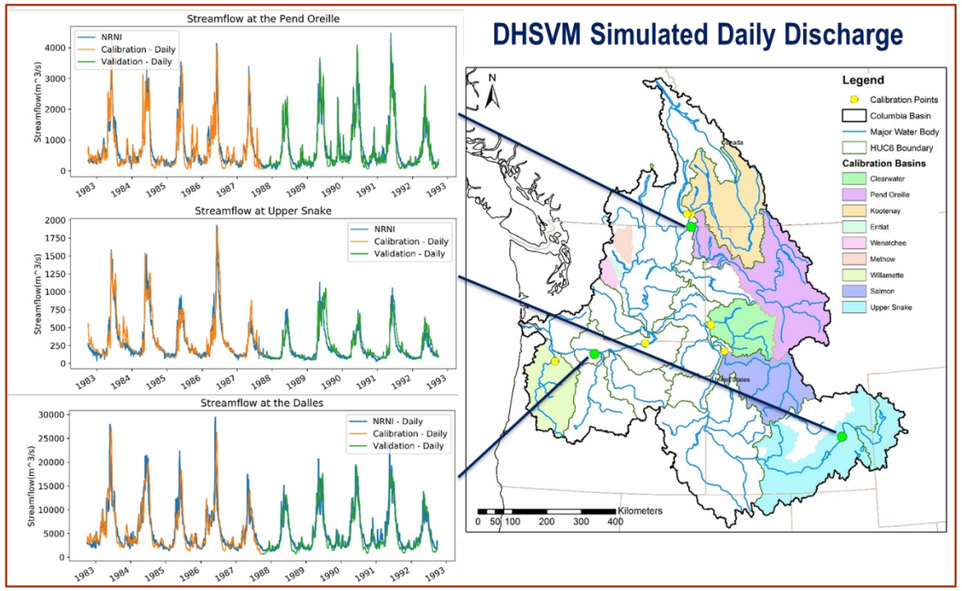
The TCSI boundary.

- Led by the USDA Forest Service Pacific Southwest Research Station
  - Multiple collaborators
- Prioritization of forest management under different scenarios of ecosystem service valuation based upon a consideration of potential market values and non-market values including **water, carbon, wood products, tribal cultural values, biodiversity, and fire risk reduction**
- Partners: USFS Region 5, Blue Forest Conservation, Quantified Ventures, Tahoe Central Sierra Initiative

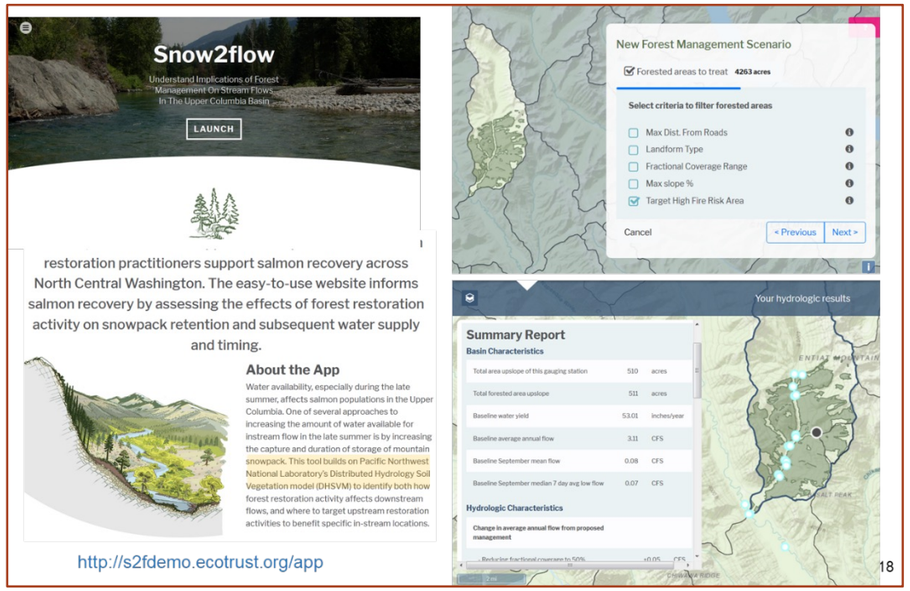
2021-2023: ***Expanding Forest Management and Promoting Ecosystem Services through access to Environmental Markets,*** funded by the USFS Region 5 National Conservation Investments Program

This study seeks to quantify and value ecosystem services in a manner that facilitates market investments in funding new and existing restoration projects on National Forest lands by constructing and utilizing a portfolio of ecosystem service benefits.

Follow on Funding: Supporting Multi-Objective Forest Management in the Pacific Northwest Columbia Basin



2021/2023: ***Improving the Timing and Volume of Hydrosystem Inflow through Targeted Forest Management***, U.S. DOE Waterpower Technologies Office



2020-2021: ***Refine and Pilot Test Upper Columbia Distributed Hydrology Soil Vegetation Model and Snow2Flow Decision Support Tool***, Upper Columbia Salmon Recovery Board (NGO) / Washington State Department of Ecology

3 – Impact

Continued Engagement with the Washington Water Trust, Blue Forest, WA DNR, and the Colville Confederated Tribes

- Increase our collaboration with the Washington Water Trust to integrate land and water management to accelerate innovation, development, and implementation of a restoration economy through application to the NSF Regional Innovation Engines program, a 10-yr 160 MM$ award.
  - March 28th, 2023 Planning Workshop, Colville, WA

- Continued engagement with Blue Forest restoration investment activities (private equity) in the Wenatchee Basin and upper Wenatchee Pilot Project.

- Understand the Colville, Spokane, Nez Perce Confederated Tribes' concerns, their prior experiences, and gauge their support for the application of our analysis framework on Tribal lands through education of our analysis capabilities and prior work

Summary

- **Overview:** This project is using a linked set of spatial, biophysical models coupled with existing USFS decision support software to develop and demonstrate an analysis framework to prioritize how and where to target forest restoration to address multiple objectives
- **Management:** Task-driven approach following BETO management protocols
- **Approach:** Integrate detailed spatiotemporal data with biophysical models for multi-scale tradeoff analysis using the USFS EMDS (Ecosystem Management Decision Support)
- **Progress & Outcomes:** Completed 100-year application of the DST to Wenatchee Basin (historical climate) for multi-objective tradeoff analysis considering biomass, carbon, wildfire and smoke emissions, snowpack/streamflow, and economics.
- **Impact:**
  - Significant two-way knowledge and technology transfer through follow-on Federal and State funding for six projects.
- **Future Work:**
  - Implement the impacts of climate change via downscaled 21st century predicted weather streams
  - Expand the application domain to include 2 new basins
  - Continued outreach to the science, policy, and industrial communities

Quad Chart Overview

Timeline

- Project start date: 10/1/2022
- Project end date: 9/30/2025

	FY 22	Total Award
DOE Funding	$250,000	$500,000 (FY 2021-2022)
Project Cost Share*	$0	$0 (FY 2021-2022)

TRL at Project Start: 2-3
TRL at Project End: 2-3

Project Goal

Provide reasonable estimates of time-dependent, spatially explicit, forest restorative, and ongoing maintenance treatments that are required over 10 decades to stabilize landscapes, their sequestered carbon, burned area, smoke emissions, water resources, and biomass opportunity.

End of Project Milestone

Estimate the scale (percent of the basin) of spatially explicit, time-dependent forest treatments required (over decades) to stabilize landscapes, their carbon, their burned area, smoke emissions, their water resources, and their biomass opportunity amidst warmer and drier future climates in all demonstration basins.

Funding Mechanism

BETO Lab Call

Project Partners*

- USDA-FS, Pacific Northwest Research Station

*Only fill out if applicable.

Additional Slides

Go/No-Go

Go/NoGo Decision			
Name	Description	Criteria	Date
Viability of collaboration with the Washington State Department of Natural Resources (WADNR) as a mechanism for technology transfer	Provide BETO a written evaluation (white paper) on how WADNR would want to build on the project or leverage different aspects to assist with their 20-year Forest Health Plan. This will be used to understand the viability of collaboration with the WADNR as a mechanism for technology transfer.	The viability of collaboration Washington State Department of Natural Resources (WADNR) as a mechanism for technology transfer will be based on the willingness of WADNR to fund the project team to assist in their efforts. If WADNR provides funding, we will recommend a Go decision.	3/31/2021

WADNR has funded two follow on projects (slide 14)

- Landscape Management Simulator (2023)
- Modeling Landscape Scale Treatment Effects on Snowpack and Streamflow (2022)

Responses to Previous Reviewers' Comments

Comment: While the goal states that this project will evaluate GHG emissions, GHGs weren't actually covered anywhere.

Response: This research considers smoke emissions (i.e., total carbon release and PM2.5 and PM10) rather than the full suite of GHG emissions. The research will not assume that there are immediate benefits to smoke emissions. Smoke emissions will increase for a period of decades until the effects of 150 years of fire exclusion are minimized. We intend to use weather streams consistent with late 20th century (RCP4.5) and late--21st century predictions for the RCP 8.5 GHG emissions scenario on the fully calibrated DHSVM hydrologic model and for 100-year LANDIS II vegetation growth simulations.

Our simulated fuel treatments will begin at year 1 and will continue until year 100. Wildfires that exceed a 97th percentile fire weather threshold will be allowed to burn each year. Until the sum of escaped wildfires plus forest and fuel treatments treat a large enough portion of the landscape, we expect emissions to steadily increase. This is a consequence of a fire deficit coupled with a fuel surplus. Until the fuel surplus is adequately depleted, emissions will remain high and then drop off to a metastable condition. Thereafter, we will show the benefits of wildfire smoke emissions reductions through forest thinning and Rx burning and collecting biomass for energy use, and long-term wood in service.

Responses to Previous Reviewers' Comments

Comment: This research could incorporate burn probability modeling and carbon stock assessments to evaluate both the severity and likelihood of fire in order to map out risk.

Response: Rather than using burn probability estimation in our risk assessment, we are modeling flame length probability and crown fire initiation and spread potential. Flashy grass and shrub fuels have the highest burn probability each year and they release the least emissions. Thus, probable burned area is not a useful measure of the effects of treatments on forest mortality or emissions. With high flame lengths, the likelihood of forest burning or reburning is highest, likewise for crownfire initiation and spread potential. Management treatments involving thinning and burning reduce fuel ladders and surface fuels thereby reducing flame lengths and crown fire potential. These will be our metrics modeled over 100 years. We will be able to show land sector carbon stocks (and perhaps soil carbon) associated with each treatment year.

Publications, Patents, Presentations, Awards, and Commercialization

- **Publications**
  - Povak NA, Furniss TJ, Hessburg PF, Salter RB, Wigmosta M, Duan Z and LeFevre M (2022) Evaluating Basin-Scale Forest Adaptation Scenarios: Wildfire, Streamflow, Biomass, and Economic Recovery Synergies and Trade-Offs. *Frontiers in Forests and Global Change.* 5:805179. doi: 10.3389/ffgc.2022.805179
  - Tucker JF, PF Hessburg, NA Povak, RB Salter, MS Wigmosta (2022), Predicting future patterns, processes, and their interactions: Benchmark calibration and validation procedures for forest landscape models, Ecological Modelling, Volume 473, doi.org/10.1016/j.ecolmodel.2022.110099.
  - Sun, N., Yan, H., Wigmosta, M. S., Lundquist, J., Dickerson-Lange, S., & Zhou, T. (2022). Forest canopy density effects on snowpack across the climate gradients of the western United States mountain ranges. Water Resources Research, 58, e2020WR029194. https://doi.org/10.1029/2020WR029194
  - The Washington State Academy of Sciences (WSAS) published proceedings of the 12th symposium, “Wildfire in Washington State” which includes results from our project entitled “Evaluating Tradeoffs for Water, Fire, Biofuels, and Fish”. http://www.washacad.org/wp-content/uploads/2019/11/Twelfth-Symposium.pdf
  - Sun N, Wigmosta M, Zhou T, Lundquist J, Dickerson-Lange S, Cristea N. 2018. Evaluating the functionality and streamflow impacts of explicitly modelling forest–snow interactions and canopy gaps in a distributed hydrologic model. Hydrological Processes;1–13. https://doi.org/10.1002/hyp.13150.

Publications, Patents, Presentations, Awards, and Commercialization

- **Presentations**
  - Wigmosta, M., Yan, H., Duan, Z., Sun, N., Gutmann, E., and Arnold, J. (2022). “Implementing hydrologic design to address non-stationary climate.” 2022 AGU Fall Meeting, Chicago, Illinois
  - Duan Z., H. Yan, M.S. Wigmosta, E. Gutmann, and J. Arnold.(2002). "Impacts of Forest Cover on Hydrologic Extreme Events over the Conterminous United States: Changes and Mechanisms." 2022 AGU Fall Meeting, Chicago, Illinois
  - Wigmosta M.S, Z. Duan, et al. 2019. "Assessment of Sustainable Biomass through Forest Restoration." Presented by Z. Duan at 2019 AGU Fall Meeting, San Francisco, California.

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Thank you