Pacific Northwest
NATIONAL LABORATORY

Sustainable Biomass through Forest Restoration

March 10, 2012
Data, Modeling & Analysis

Mark Wigmosta

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

Project Overview

- In 2020, the Western United States experienced a series of major wildfires killing at least 37 people and causing over $19.9 billion in damage and $3.4 billion in fire suppression costs. Climate change and poor forest management practices contributed to the severity of the wildfires.
- In 2018 wildfires contributed 150 Tg CO_2e in continental U.S.
- Forest management activities including commercial harvest 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 reduction in
    - The intensity of wildfire and smoke emissions
    - Smoke associated with prescribed burning for residue disposal
  - Concurrent hydrologic benefits – increased streamflow volumes and improved timing with associated ecological benefits
  - Economic and societal benefits through collection of residue for bioenergy (e.g., rural employment)

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.

1 – Management

Task Coordination

PI/PM Wigmosta (PNNL)
PI Paul Hessburg (USFS)
Project Coordinator: Lilly Burns-Pearson (PNNL)

- Following BETO project management protocols
  - Annual Operating Plan (AOP)
  - Quarterly Progress Reports to BETO
- 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:
    - Upper Columbia Salmon Recovery Board;
    - WA Department of Natural Resources;
    - USDOE Waterpower Technologies Office
    - University of Washington;
    - University of Nevada Reno
- Project Risk
  - Potential delays associated with USFS funding through an Interagency Agreement (IAA)
  - Lack of certain data or inputs

Task	Lead
Simulation of vegetation regrowth to better estimate long-term biomass supply and impacts to wildfire intensity and streamflow	Hessburg (USFS)
Capture uncertainty in forest restoration impacts to streamflow	Wigmosta (PNNL)
Outreach and technology transfer to the science, policy, and industry community's	Wigmosta/Hessburg

1 – Management

Risk Mitigation

Name	Status	Target Completion Date	Severity	Response	Description
Schedule	Issue	9/30/2022	Medium	Risk will be mitigated by active oversite by the Project Coordinator and beginning any modifications to Interagency Agreement (IAA) early. Continued regular communication with BETO and discussion of schedule/scope changes in advance	The USFS receives funding through an IAA. Delays in processing invoices or modifications to the agreement can impact the schedule
Scope	Issue	9/30/2022	Low	Regular communication with BETO and discussion of alternatives to achieve completion	Lack of certain data or inputs. Delay in hand-offs of data in a timely manner from other partners that could impact our ability to complete work in a timely manner

Forest Restoration Scenarios for a Fire-Dominated Landscape

- Previous land management has led to increased surface and canopy fuels

- **Goal:** Restore landscape to a pattern more consistent with the native fire regime
  - More frequent, less intense wildfire
  - Complex mosaics of individual trees, tree clumps, and openings (gaps)

Major Assumptions

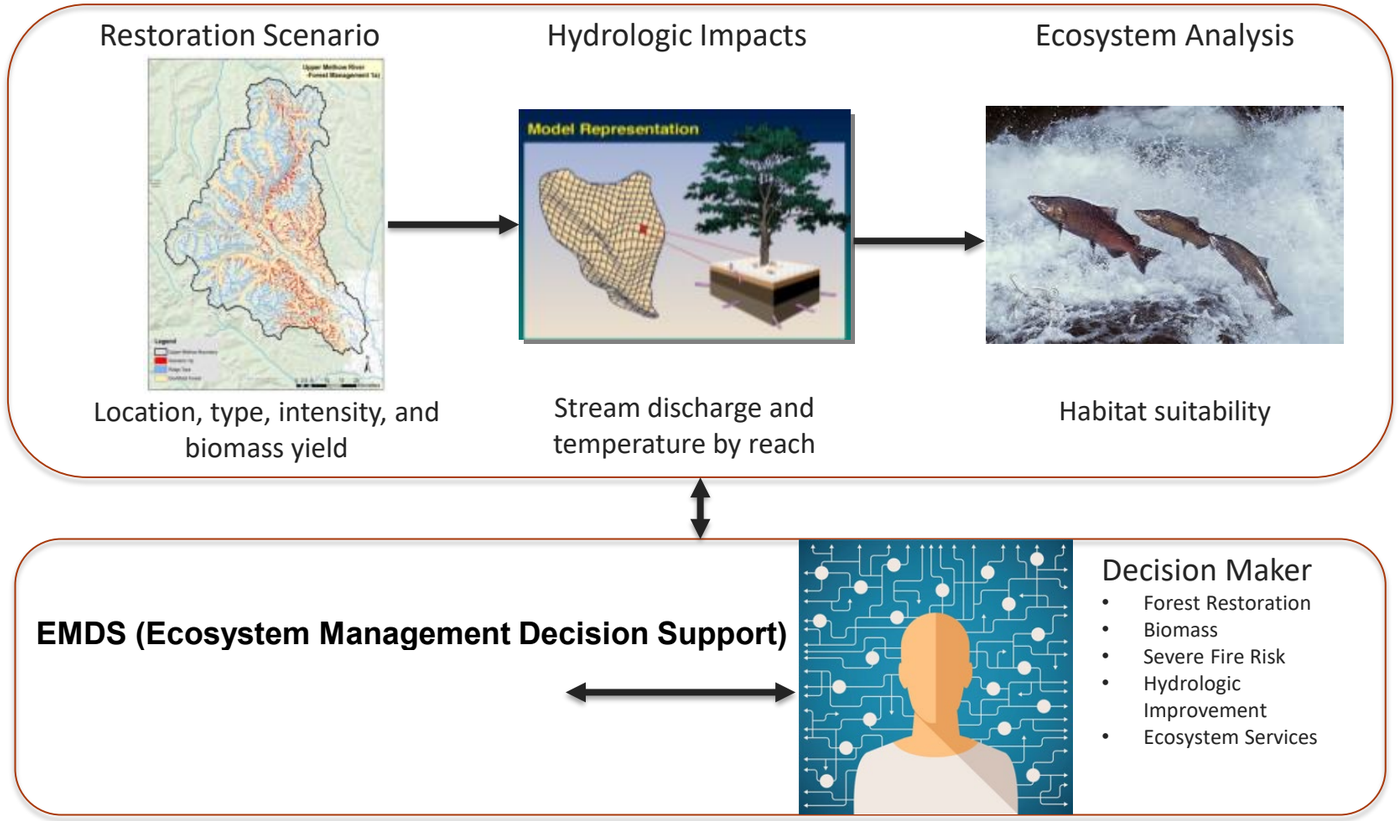
- Restoration through:
  - Commercial thinning + prescribed burning
  - Prescribed burning in other locations

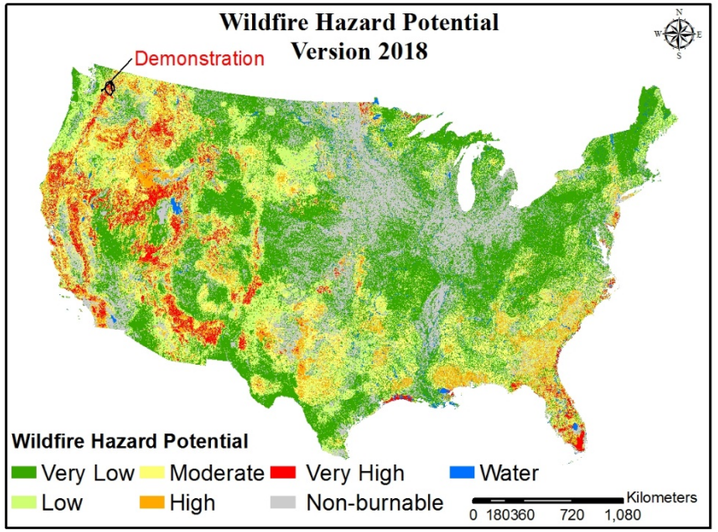
- Only consider biomass for energy associated with the commercial activities
  - No monetary or regulatory incentives

(From WDFW Thinning treatments at Sinlahekin Wildlife Refuge

2 – 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

2 – Approach

Technical Success and Key Challenges

- **Technical Success**: Analysis framework prioritizing how/where to target restoration
  - Dissemination of study results through peer-reviewed publications, conferences and workshops
  - Technology transfer through USFS EMDS decision support software
  - Leverage existing PNNL/UCSRB/Ecotrust “Snow2Flow” modeling and decision support system
    - Technical Advisory Group: National, State, and Local agencies, Forest Products Industry, Tribes, and NGO’s (e.g., TNC)
    - Web-based Interface
  - Leverage existing Waterpower Technologies Office modeling to extend research to the regional scale
- Key Challenges
  - State of the Science – limited datasets for model validation
  - Adequate datasets for application for other regions in U.S.
  - Conflicting feedback from industry and stakeholders
    - Objectives
    - Priorities
    - Approach

Collaboration with Washington State Department of Natural Resources will be elucidated

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

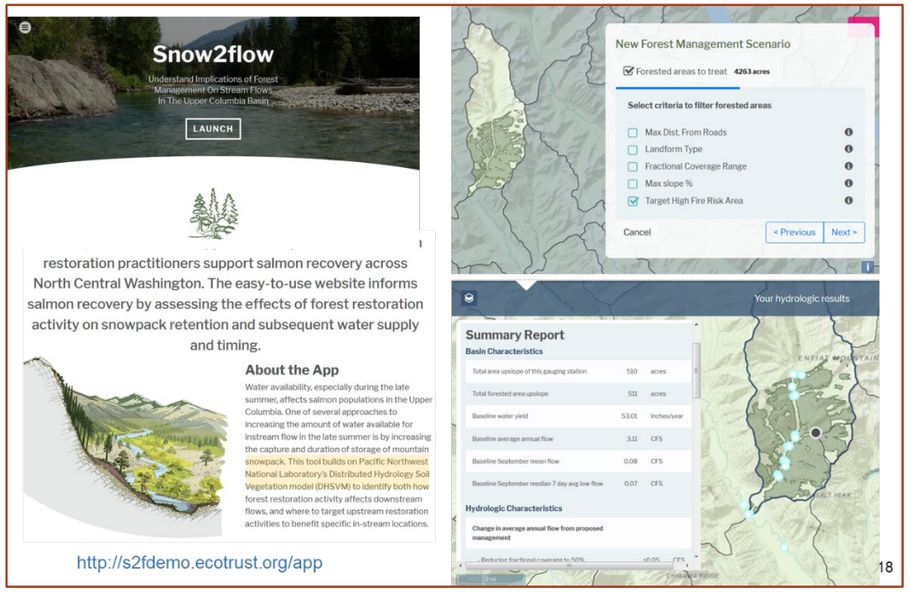
- On track to develop white paper by 3/31/2021 based on previous/ongoing discussions with WADNR
- Impact to Washington State budget due to COVID 19 makes it unlikely we will receive direct funding from WADNR in FY 2021. We anticipate funding when the State budget improves.

Pacific Northwest NATIONAL LABORATORY

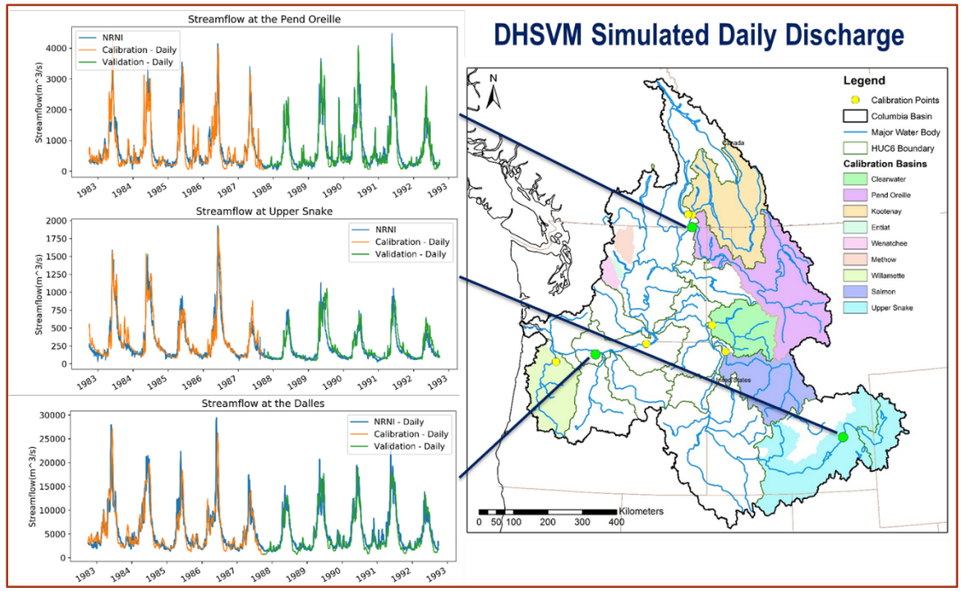
PNW

3 – Impact

Current Follow-on Funding



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



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

2019 Peer Review: “Project is extremely relevant - forestry biomass - has been identified in each of the ‘Billion Ton’ studies as a major source of biomass. Developing and providing decision support tools demonstrating harvesting of forest materials can be done sustainably and lead to environmental benefit is essential. Reduce forest fire risk - additional planning and decision support tools are needed to assess ecosystem services.”

3 – Impact

Current Follow-on Funding (continued)

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

2021-2022: ***Expanding Forest Management and Promoting Ecosystem Services through access to Environmental Markets,*** funded by the USFS Region 5 National Conservation Investments Program

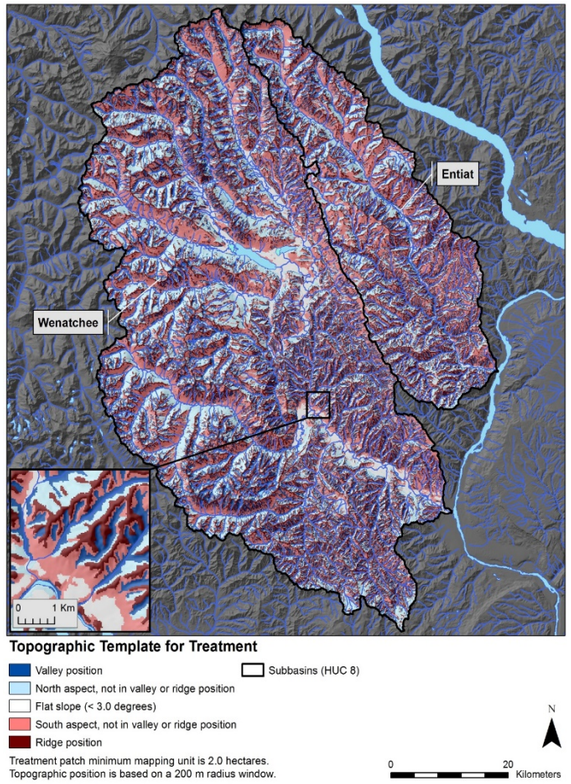
This study seeks to quantify and value ecosystem services in a manner that facilitates market investments in funding new and existing restoration projects on National Forest lands by constructing and utilizing a portfolio of ecosystem service benefits.

3 – Impact

Additional Outreach

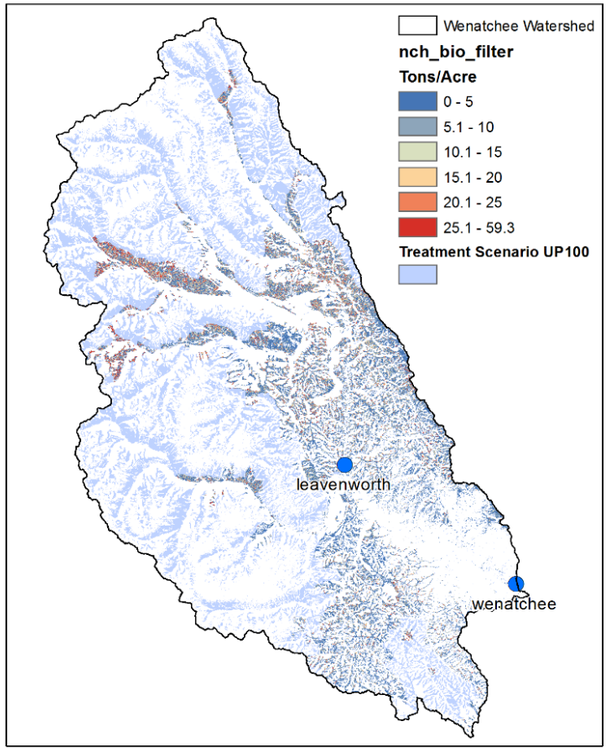
- Additional Outreach
  - Ongoing discussions with Washington State Department of Natural Resources on opportunities to build on the project or leverage different aspects to assist with their 20-year Forest Health Plan
  - Ongoing discussions with Blue Forest and the Forest Resilience Bond for potential collaboration on Forest Restoration opportunities
- Key Presentations
  - Biomass R&D Board (invited)
  - Wildfire in Washington State, Washington State Academy of Sciences (invited)
  - American Geophysical Union 2019 & 2020 Fall Meeting
- Recent Publications
  - 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”
  - 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
- Invited Paper in Preparation
  - Decision Support for Evaluating Basin-Scale Restoration Scenarios: Wildfire, Streamflow, Biomass, and Economic Recovery Trade-offs, Frontiers in Forests and Global Change, special issue on Wildfire Management and Decision Support

Forest Treatment Scenarios and Associated Biomass Available for Energy



Treatment on south-facing slopes and ridgetops for fuel reduction

Non-merchantable biomass removed in thinnings



Harvest residue available for bioenergy (via FVS) close to existing roads

Treatments prescribed at the patch scale (10's – 100's of hectares) to properly reflect site topography, vegetation, climate, and road access on the type and intensity of treatment

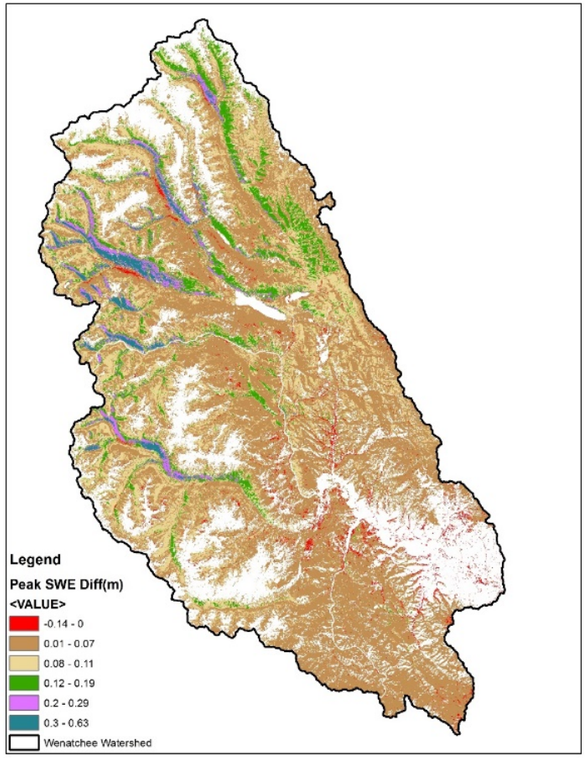
Metrics to quantify the tradeoff analysis

- Fire
  - Burn intensity (flame length, crowning index)
  - Total carbon release
  - Smoke production (PM2.5 and < PM10)
- Biomass
  - Merchantable
  - Non-merchantable (residue for energy)
- Hydrology
  - Snowpack characteristics
  - Streamflow (annual, monthly, late season)
- Economics
  - Collection costs
  - Hauling costs

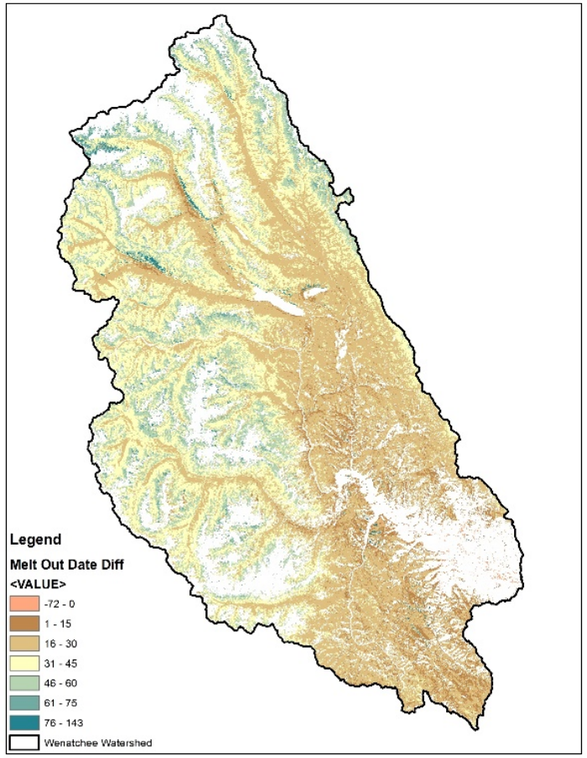
- Forest management is spatially explicit
- **Values** for key metrics quantify the reduction in wildfire risk and smoke emissions, available biomass, impacts to streamflow, and associated economics
- These spatially variable metrics help quantify the synergies and tradeoffs between objectives
- Trade-offs are reflected in the Decision Support Tool (DST)

Forest Canopy Conditions Impact the Volume and Timing of Snowmelt at the Patch Scale

Difference in Peak Snow Water Equivalent
(Treatment – Baseline, meters)

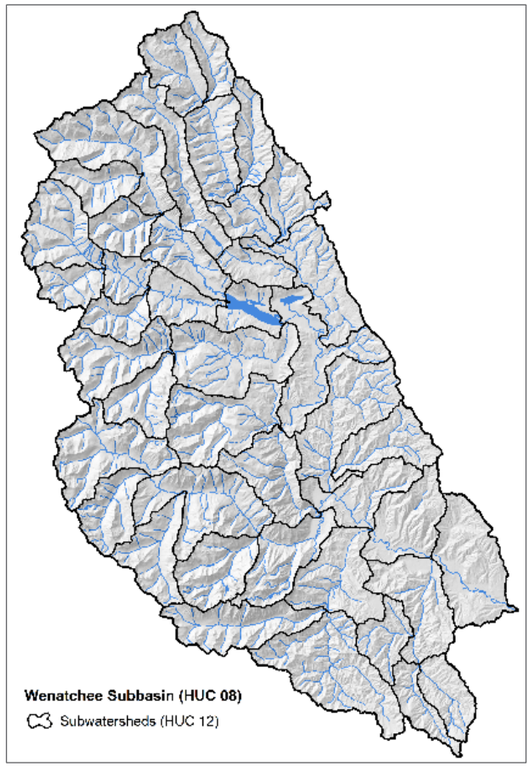


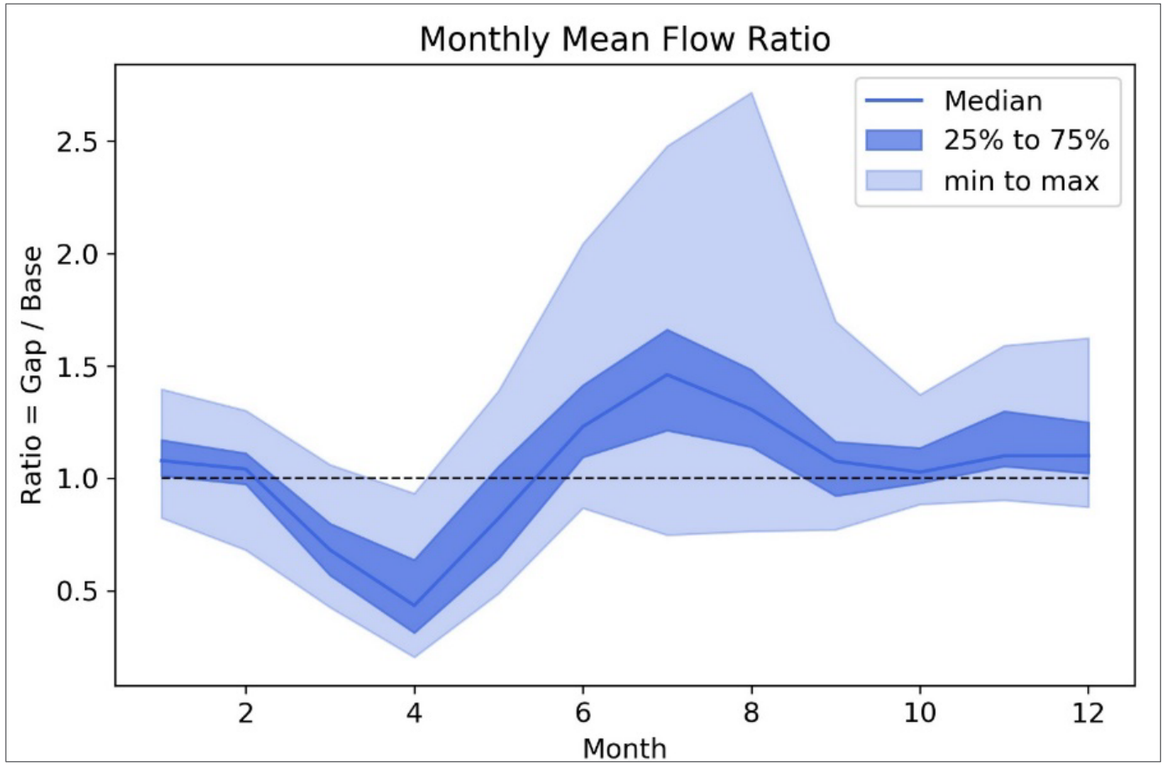
Difference in Disappearance of Snowpack
(Treatment – Baseline, days)



- Topography, vegetation, and climate drive simulated patch scale, spatial-temporal snowpack responses to forest treatment
- General increase in snowpack peak water storage and duration

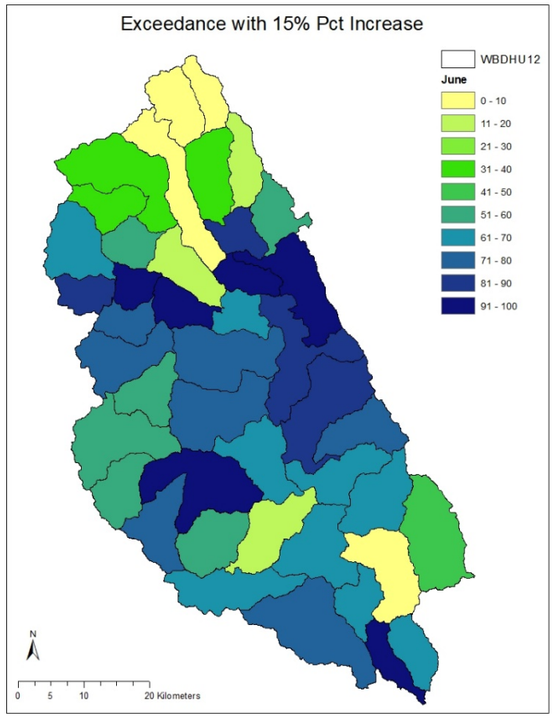
The Streamflow Response to Forest Management is Location Specific and Driven by Seasonal Climate/Meteorological Conditions

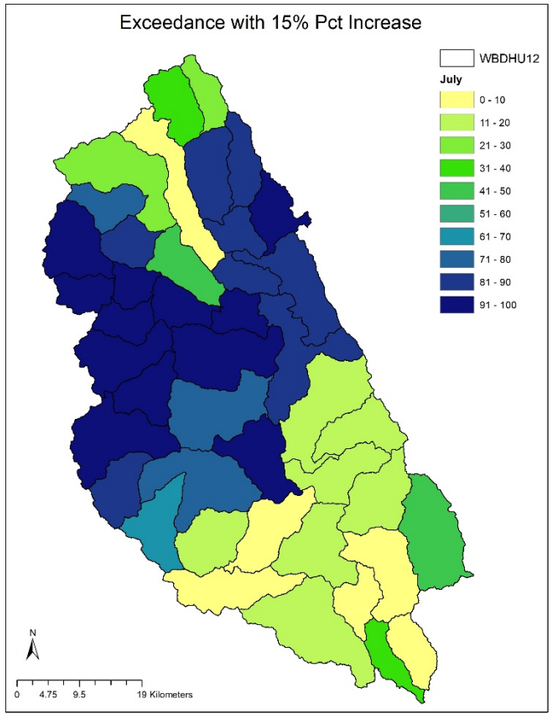


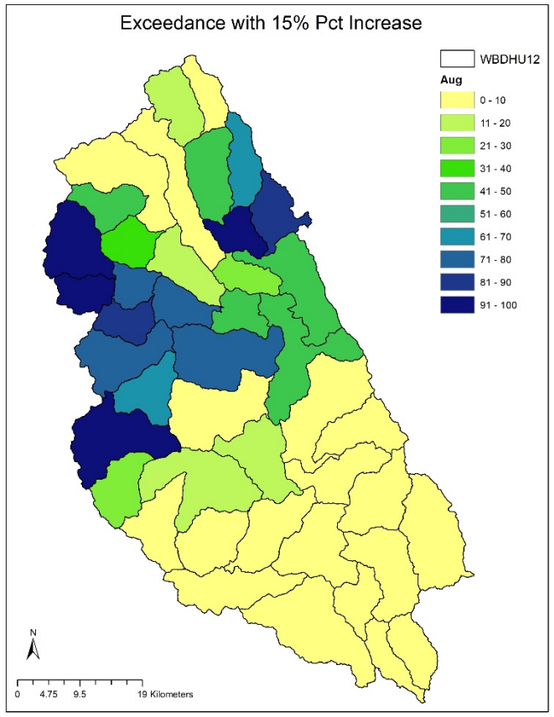


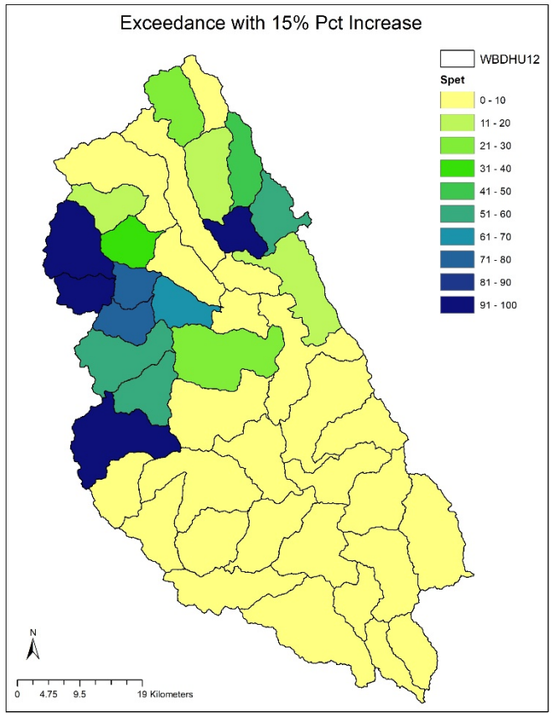
- The “direction” and/or magnitude of change may switch from year-to-year at the same location depending on climate variability
- Targeted actions can aid by increasing late season flows, while potentially reducing peak flows during the fall and winter to better meet salmonid habitat requirements (Flitcroft et al., 2016)

Probabilistic Approach - Likelihood of Achieving a 15% Increase in Critical Summer Low Flow





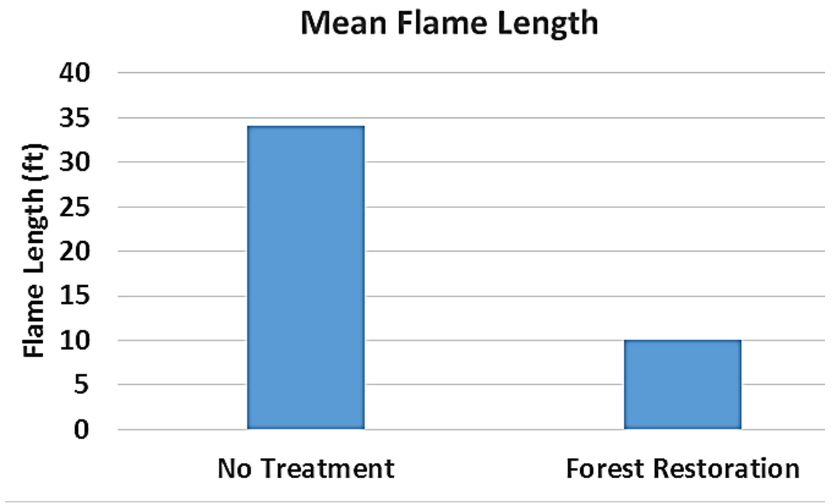




The mid to northern portion of the basin show a relatively high likelihood of achieving a 15% or greater flow increase in June and July. A subset of these basins maintain a relatively high likelihood of meeting the target through September. Locations with a greater probability of achieving this target may be prioritized for restoration from a hydrologic perspective.

Reduction in Wildfire Risk Through Forest Restoration

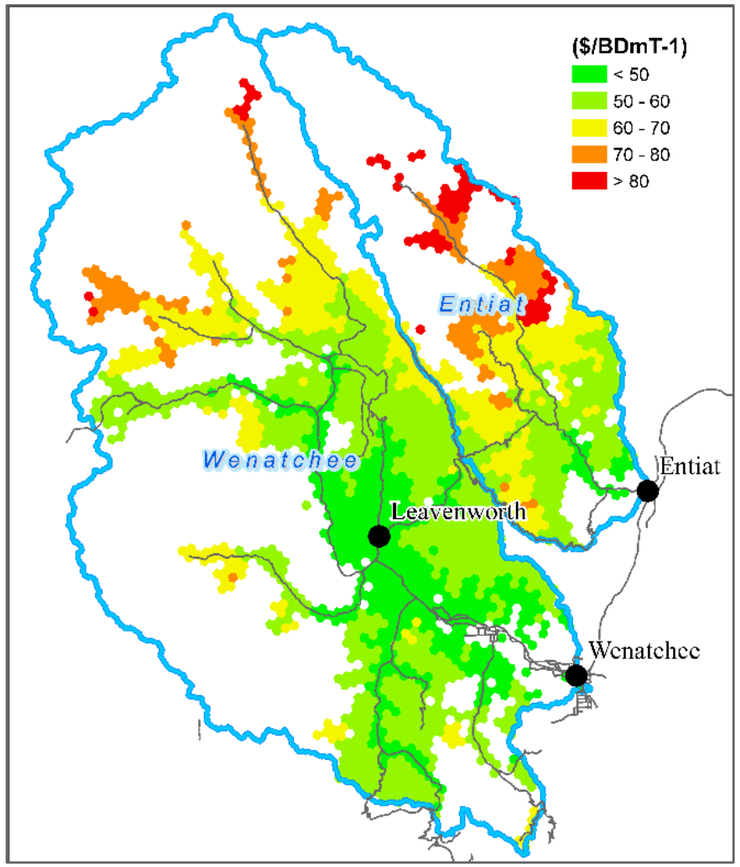
- **Flame length** under severe weather conditions, indicates the likelihood that direct fire suppression is an option
  - Current evaluation is for restored locations. We can also model change in likelihood of spread between treated and untreated locations, not shown here.



- Significant reduction in flame length on treated pixels
- More detailed analysis of wildfire spread is underway

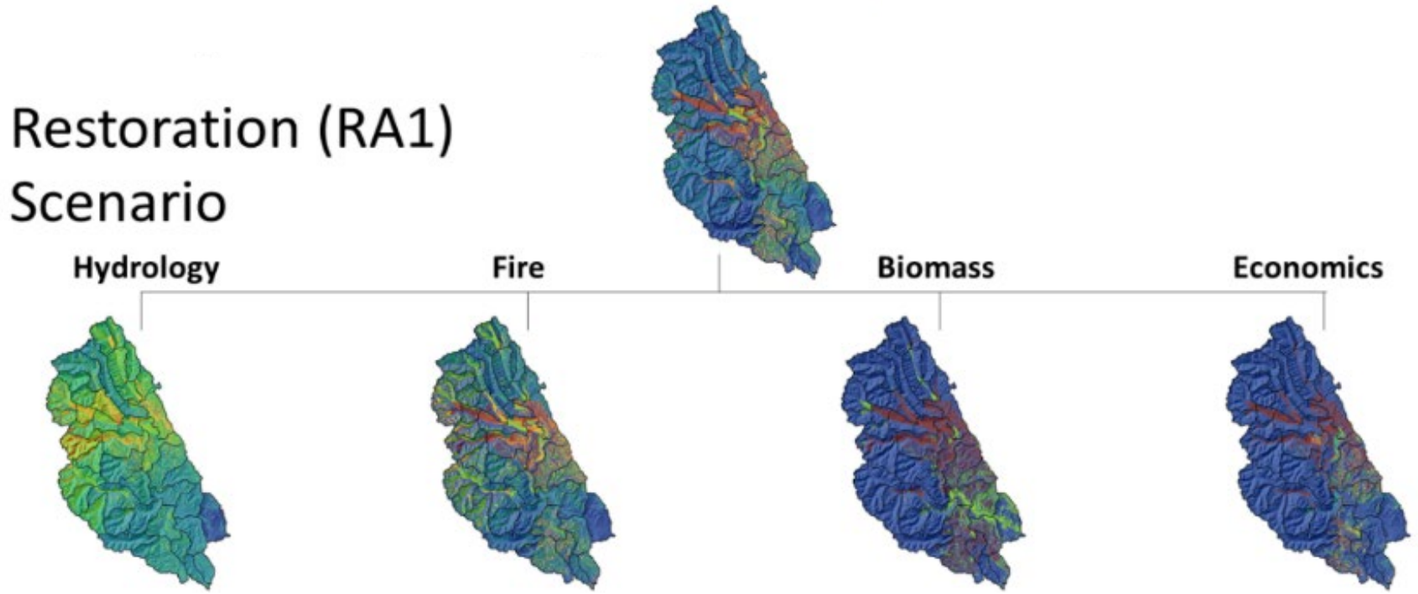
The Economics of Forest Biomass Depends on Markets, Processing, and Transport Costs

- We simulated all forest operations using the USFS Forest Inventory and Analysis groups Biosum modeling platform
  - Models describing forest operational costs (timber falling, yarding, transport) and user provided forest product values to summarize the economic components of forest treatment scenarios
  - Per acre values for merchantable and non-merchantable biomass volume and value, as well as the total operational costs
  - Hauling costs taken as the product of total per-acre biomass volume and per-ton hauling cost rates
  - Most current Washington State Department of Natural Resources pricing information for the eastern Washington market



The road network is a major driver of the delivered cost of residue

Examining the Tradeoffs Between Bioenergy, Wildfire, Water, and Economic Sustainability



- **Upper Panel:** Priority locations (warm colors) for forest treatments based on land allocation, derived benefits to hydrology, wildfire risk and smoke emissions reductions, available biomass, and economics
- **Lower Panel:** Priority locations for individual objectives used in tradeoff analysis

The DST provides transparency in the tradeoff analysis by allowing the impact of each major objective to be assigned more or less importance relative to others to reflect stakeholder values, which is illustrated by changes the priority locations in the upper panel

- Fire
  - Burn intensity (flame length, crowning index)
  - Total carbon release
  - Smoke production (PM2.5 and < PM10)
- Biomass
  - Merchantable
  - Non-merchantable (residue for energy)
- Hydrology
  - Snowpack characteristics
  - Streamflow (annual, monthly, late season)
- Economics
  - Collection costs
  - Hauling costs

Key Findings from Tradeoff Analysis with Equal Weighting of Objectives

- Targeted actions can aid by increasing late season flows, while potentially reducing peak flows during the fall and winter to better meet salmonid habitat requirements
- The highest priority locations for hydrology are mostly in the upper elevations in the western portions of the subbasin, but were not ultimately identified as high priority in the final priority scores due to limited economically viable biomass
- Locations with a high likelihood of high-severity fire do not necessary represent areas with the greatest potential for smoke production due to differences in climate, forest type, and management
- Particularly in mid- to low-elevation forests, burning alone cannot reduce fire hazard or emissions as effectively as mechanical treatments in combination with prescribed burning
- The road network is a major driver of delivered cost of residue
- Locations with a high final priority for treatment were spatially concentrated and resulted in large net benefits to all four primary topics, including the potential to increase snowpack, annual flow volume, and critical late season low flows

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)
- **Impact:**
  - Follow-on funding from 1) Upper Columbia Salmon Recovery Board (NGO) / Washington State Department of Ecology, and 2) US DOE Waterpower Technologies Office, 3) USFS Region 5 National Conservation Investments Program
  - Coordinating with Washington State Department of Natural Resources
- **Progress & Outcomes:** Completed prototype application of the DST to Wenatchee Basin for multi-objective tradeoff analysis considering biomass, wildfire and smoke emissions, snowpack and streamflow, economics
- **Current/Future Work:**
  - Simulation of vegetation regrowth
  - Capture uncertainty in forest restoration impacts to streamflow
  - Continued outreach to the science, policy, and industry community's

Quad Chart Overview

Timeline

- Project start date: 10/01/2019
- Project end date: 9/30/2022

	FY20	Active Project
DOE Funding	$250,000	$750,000 over 3 years

Project Partners

- Partner 1: US Forest Service – Pacific Northwest Research Station
- Partner 2: Yetta Jager, ORNL, 4.2.1.42 Geospatial Analysis of Ecosystem Service Portfolios from Biomass Production

Barriers Addressed

- St-G. Land-Use and Innovative Landscape Design
- At-B. Analytical Tools and Capabilities for System-Level Analysis
- At-C. Data Availability across the Supply Chain

Project Goal

This DOE-USFS collaboration will develop and demonstrate in a fire-prone region an analysis framework to prioritize how and where to target forest restoration (timber harvest and thinning) to have the greatest benefit for bioenergy, reduce wildfire risk and associated GHG emissions, and improve streamflow.

End of Project Milestone

Demonstrate the viability of the analysis framework as a multi-objective DST to prioritize how and where to target forest restoration (timber harvest and thinning) to have the greatest benefit for bioenergy, reduce severe wildfire risk and associated GHG emissions, and improve streamflow volume and timing.

Funding Mechanism

BETO Lab Call for FY20

Pacific Northwest
NATIONAL LABORATORY

PNW

Additional Slides

Responses to Previous Reviewers' Comments

Review Comment: This project addresses a very timely and important goal in developing and demonstrating an analysis framework to prioritize how and where to target forest restoration (timber harvest and thinning) and fuels reduction to have the greatest benefit for bioenergy, reduce severe wildfire risk, increase water yield, and improve ecosystem services. This is aligned with BETO goals. My concern has to do with the scope of the analysis they are attempting in one study. Touching on restoration ecology, fire modeling, economics, hydrology, and other analytical frameworks is a risky proposition for a project of this size.

Response: We acknowledge the broad scope of this project, given its size. Each task has a designated lead (PNNL or USFS) based on expertise. For the most part we are utilizing existing models (i.e., DHSVM, USFS Forest Vegetation Simulator and BioSum) and input datasets that have been exercised (independently) in the study domain. For example, this work builds off a previous PNNL-USFS collaboration (funded by the State of Washington) to develop a tool to estimate impact of forest restoration on streamflow in the North Central Cascades, without consideration of biomass yield or decision support. We chose to use an existing USFS decision support system (DSS) to speed technology transfer. A significant amount of effort was made early in the project to identify critical linkages and data exchange between models and the decision support system.

Publications, Patents, Presentations, Awards, and Commercialization

- 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.

- Invited paper in preparation: Decision Support for Evaluating Basin-Scale Restoration Scenarios: Wildfire, Streamflow, Biomass, and Economic Recovery Trade-offs, Frontiers in Forests and Global Change, special issue on Wildfire Management and Decision Support

Key Assumptions

- Restoration through:
  - Commercial thinning + prescribed burning
  - Prescribed burning in other locations
- Only consider biomass for energy associated with the commercial activities
  - No monetary or regulatory incentives
- Restoration scenarios applied at all locations simultaneously with no consideration of vegetation regrowth
  - This is currently being addressed by simulating forest regrowth
- Changes in wildfire intensity and smoke emissions are only evaluated in locations selected for treatment
  - This is being addressed using a more dynamic wildfire modeling capability

Restoration Scenarios to Define the Available Decision Space and can Optimize One or More Primary Topics

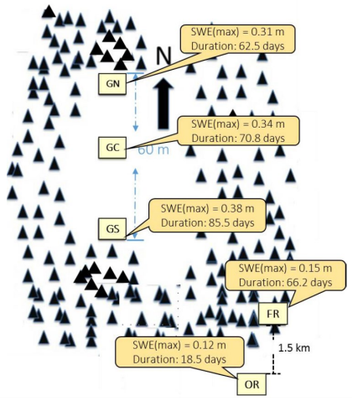
We developed our decision support tool to evaluate a variety of treatment scenarios that are intent on improving conditions in the Wenatchee subbasin. One can use such a tool to clearly define the available decision space, and to craft scenarios that can optimize one or more primary topics (Fire, Biomass, Hydrology, Economics).

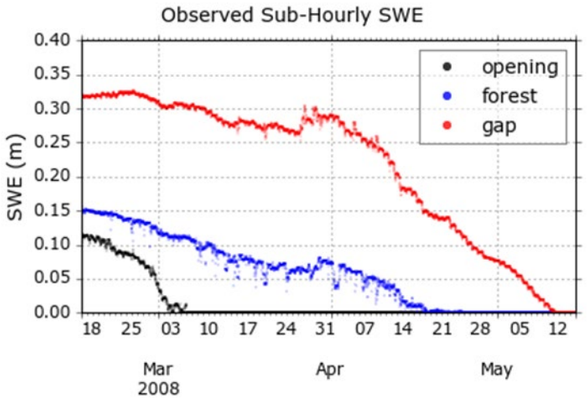
- **No treatment:** to reflect current baseline conditions.
- **Ideal Water:** Treatment designed to maximize snow accumulation and streamflow through the introduction of small gaps in the forest.
- **Max Biomass:** Treatment design to maximize fire hazard abatement and biomass objectives, while maintaining minimum standards for a thinning treatment design.
- **Burn Only:** Treatments consisted of late-season controlled burns with high fuel moisture levels for larger fuels (that are unavailable to burn), and low fuel moistures for smaller fuels (that are available to burn), and burns occur under moderate fire weather conditions.
- **Principles-Based:** Treatment design applies a principle-based approach designed to restore the landscape to a pattern more consistent with the native fire regime - more frequent, less intense wildfire with complex mosaics of individual trees, tree clumps, and openings (gaps).

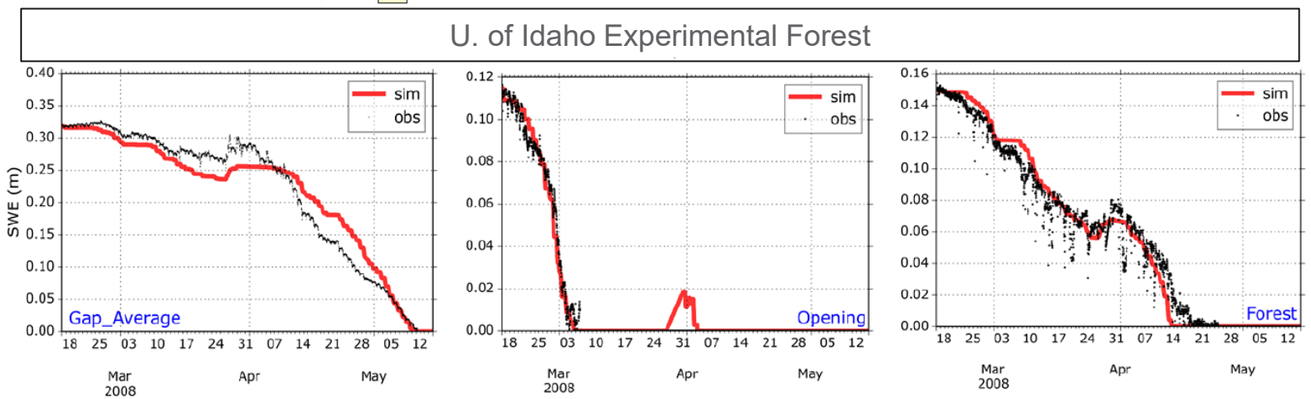
Management Scenarios are Based on Objective

Management scenario	Objective	Treatment
Maximum Biomass	Maximize the amount of chip and merchantable volume	Remove all trees when no large (>=25” DBH) are present, and all shade tolerant trees <25” DBH and all trees < 10” DBH otherwise
Ideal Water	Maximize hydrologic productivity	Within each pixel, remove all trees within a gap of size 1.2 * maximum tree height
Principles-based Restoration (RA1)	Apply a principles-based approach to landscape management (sensu, Hessburg et al. 2015)	Treat 49% of the landscape using a combination of treatment intensities
Prescribed-burning Only	Re-introduce fire as an ecological process	Implement late-season prescribed burning

Forest Canopy Conditions Impact the Volume and Timing of Snowmelt at the Patch Scale







Peak snow water equivalent (SWE) in the canopy gap is twice that of the adjacent forest, and snow cover remains ~three weeks longer

Pacific Northwest
NATIONAL LABORATORY

PNW

Thank you