Fire refugia and fire severity in forests of the Pacific Northwest: Models, drivers, and applications

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CONTEXT: Fire refugia are locations that burn less severely or less frequently than the surrounding landscape and contribute critical heterogeneity to forest ecosystems.

Fire refugia support establishment and persistence of **older forests**, providing stability for **wildlife and their habitats** under climate change.

Recent stand-replacing wildfires in old forests of the Pacific Northwest (PNW) have increased land manager and scientific interest in fire refugia that can provide important ecosystem services during a time of rapid change.

GOALS: The overall goal of this project is to model, map, and share information on fire refugia and fire severity essential for the conservation and adaptation of mature and old forest ecosystems.

STUDY AREA: We work in the PNW across western Washington, western Oregon, and northern California (Figure 1) overlapping with the Northwest Forest Plan area.

CONNECTING WITH LAND MANAGERS: The project was developed using a co-production approach, and we are currently working with implementation teams to translate research data products to real-world forest planning.
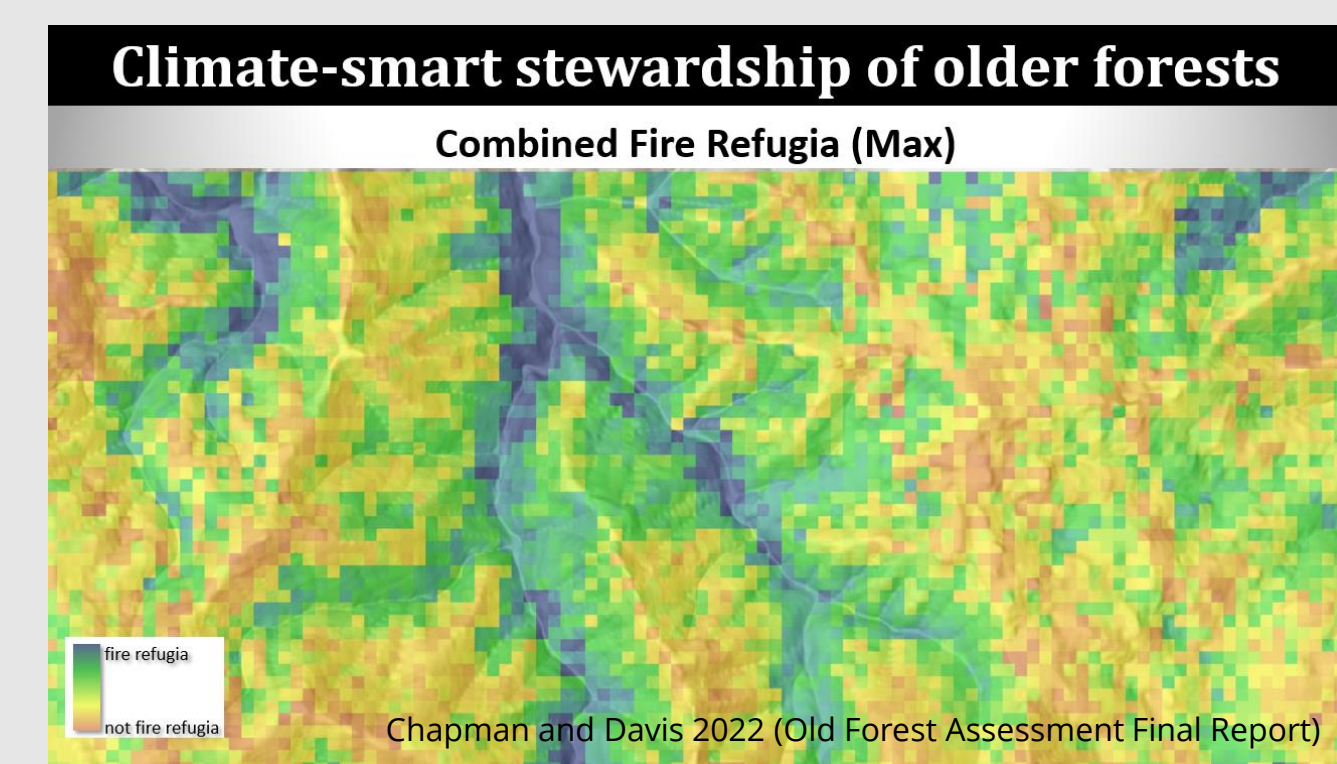
Ongoing case studies applying the fire refugia and severity maps include project areas in northern California, southwest Oregon, south-central Washington.

We recently co-produced a Fire Refugia Manager's Brief, summarizing concepts, maps, and examples to help socialize the data and provide examples for application.

Drivers of fire refugia: from models based of vegetation, terrain, and weather variables

○ Less fire prone (NOFP) - moister forests
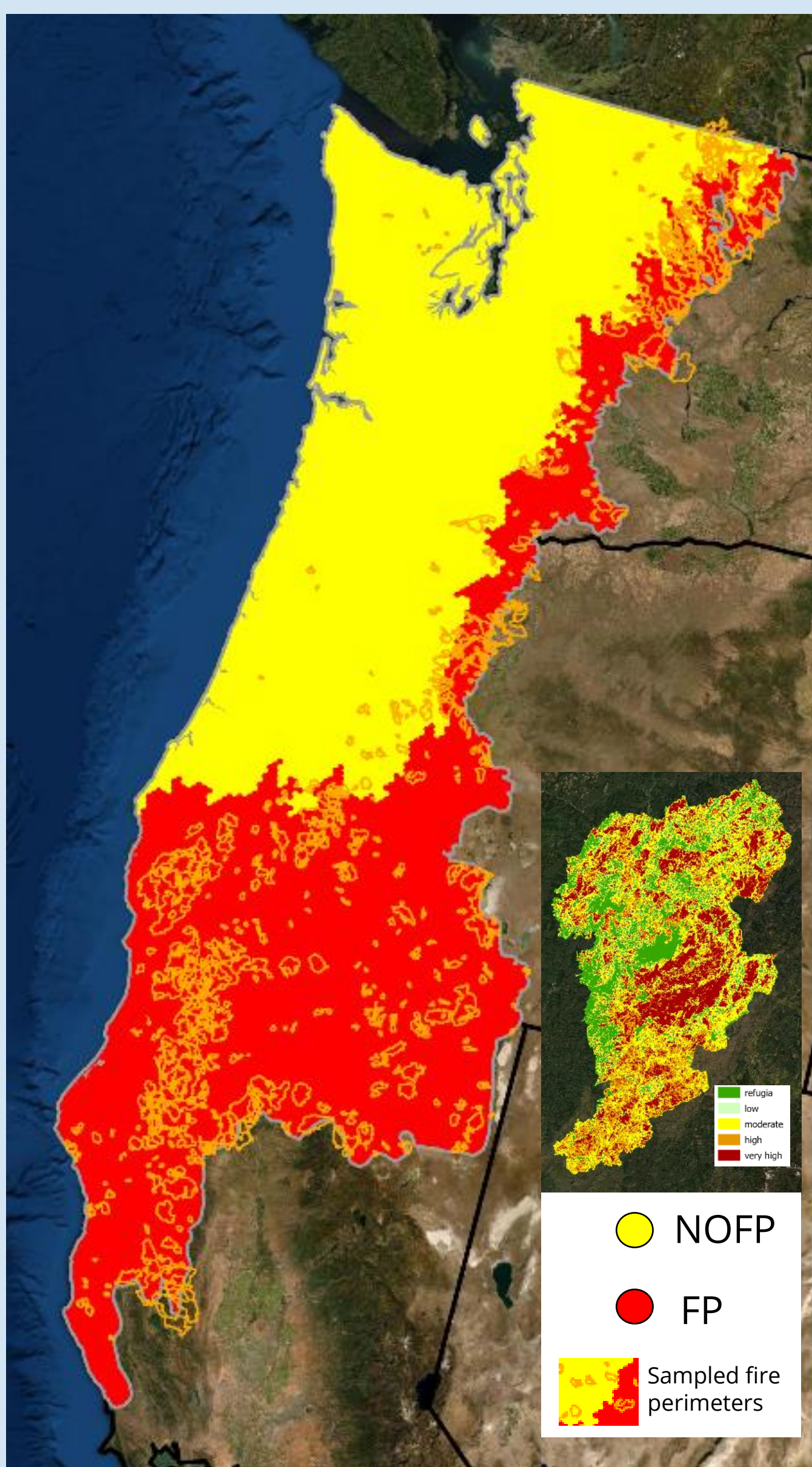
● More fire prone (FP) - drier forests

Figure 1. Map of study region, NOFP (non fire-prone) and FP (fire-prone) sub-regions, and fire locations used to train the boosted regression tree models. Burn severity estimates (rdNBR) identified fire refugia.
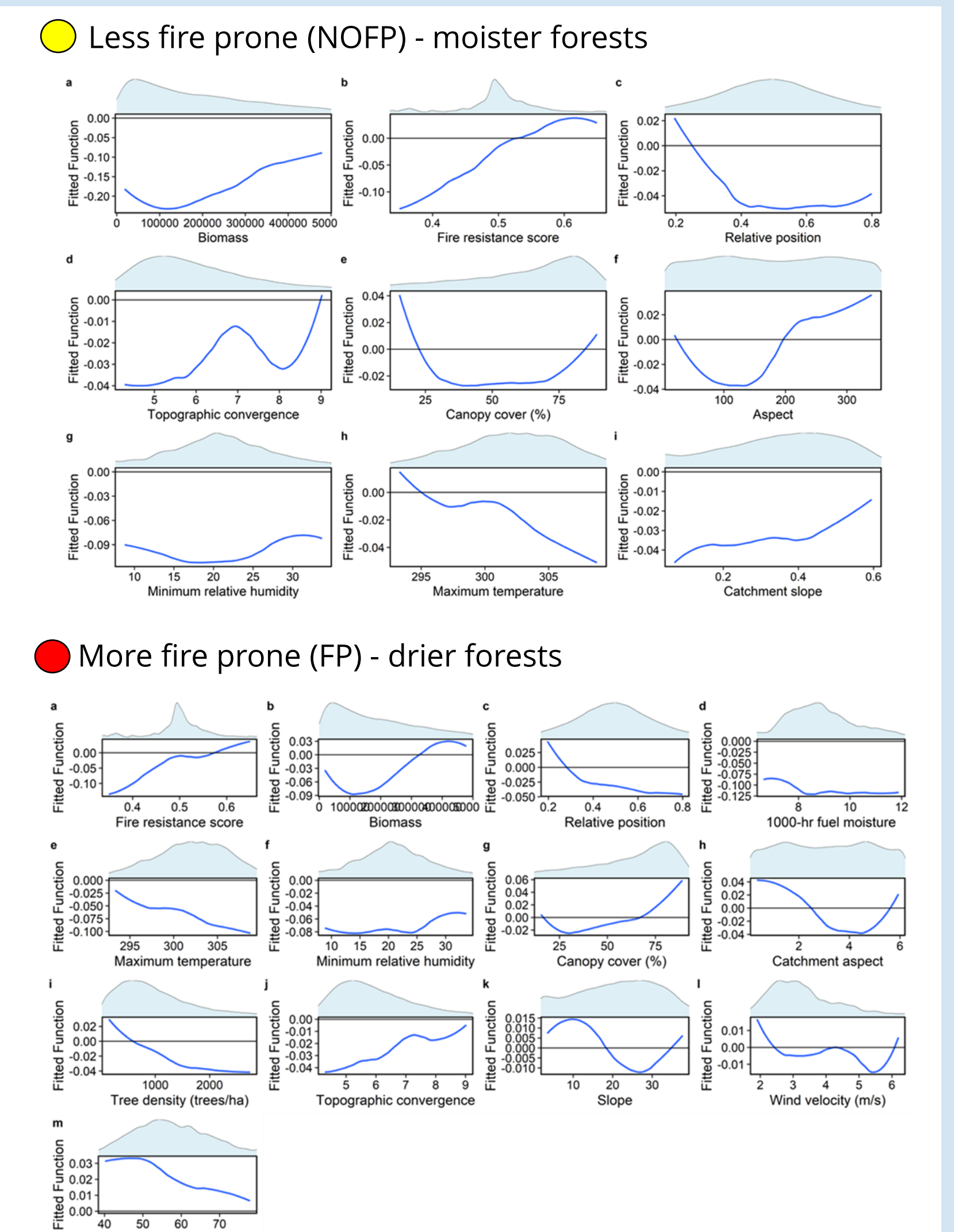
Figure 2. Response curves for drivers of fire refugia in the moist (NOFP) and dry (FP) regions based on the model scenario integrating fire weather variables.

METHODS: We developed boosted regression tree models trained on remotely-sensed contemporary (2002-2017; rdNBR) fire refugia, intermediate fire severity, and high-severity fire effects in forests, using topography, fuels/vegetation, fire weather, fire growth, and climate as explanatory variables. Models were built for non fire-prone (NOFP) and fire-prone (FP) sub-regions. This framework enabled us to represent 'normal' versus 'extreme fire growth' events – the latter exemplified by the 2020 Labor Day fire events. Ask us for more details on different scenarios!

We used these models to evaluate drivers of fire refugia (Figure 2) and severity, to produce probability surface maps for fire refugia, intermediate-severity fire, and high-severity fire, and to examine how probability shifts under low, moderate, and extreme fire weather and fire growth scenarios.

We tested the predictive capacity of the models on the 2020 and 2021 fire footprints in the region, showing the value of the modelling tools as durable predictors of forest persistence within contemporary and future fire environments.
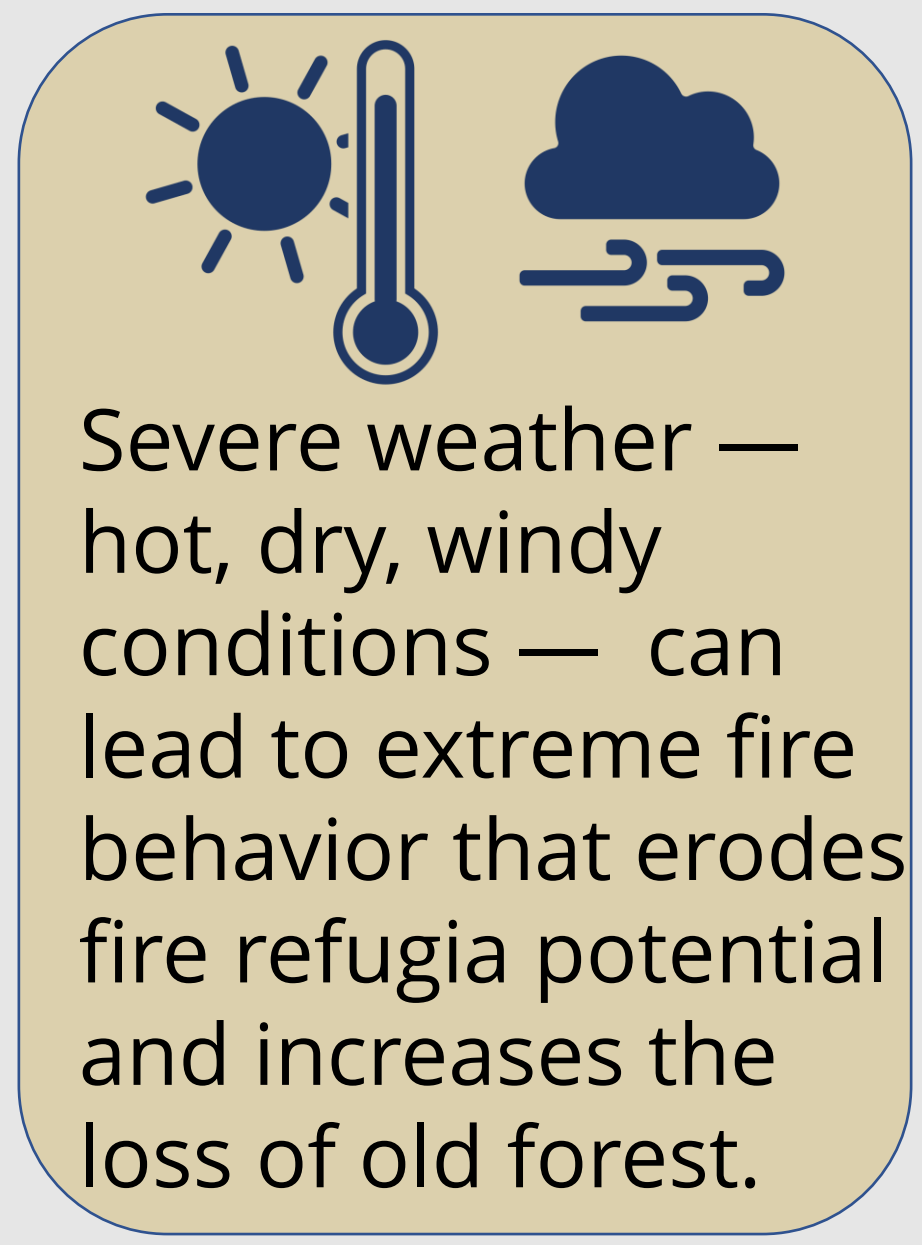

FINDINGS:

Spatial mapping of predictions from the fire refugia models show three geographic zones (wet, cold, dry) have different refugia patterns and climate sensitivities.

Understanding the composition and distribution of refugia types and how they are affected by fire weather is critical to forest conservation and climate adaptation.

**Fire refugia** — made up of living legacies of older trees — occur within all gradients of fire severity.

Severe weather — hot, dry, windy conditions — can lead to extreme fire behavior that erodes fire refugia potential and increases the loss of old forest.

Some refugia are more sensitive to fire conditions, while others are more resistant due to their topographic position and stand conditions.

	Wet Forest	Cold Forest	Dry Forest
	Many, large refugia patches	**Very few, small refugia patches**	**Distributed, small refugia patches**
Composition	Mix of fire-resistant and fire–sensitive species such as Douglas-fir, western hemlock, red cedar, true firs, Sitka spruce & red alder.	Predominantly fire-sensitive species such as lodgepole pine, subalpine fir, spruce & mountain hemlock.	Predominantly fire-resistant species such as ponderosa pine, Douglas-fir, western larch, sugar pine & oak.
Distribution	Refugia are widespread, often in large patches of high-biomass, closed-canopy forest and in topographically protected sites.	Refugia are present in small, topographically protected sites and scattered patches.	Refugia exist in a fine-grained patchwork. Surviving trees in areas of intermediate burn severity are an important source of older trees.
Fire Weather	Refugia persist under a broad range of weather conditions and are less common under extreme fire weather. Intermediate severity fire is widespread except during extreme fire weather.	Refugia are less likely to persist under all fire weather conditions. Low-moderate fire weather can yield intermediate-severity fire.	Refugia more likely to persist under mild fire weather conditions. Few refugia persist under moderate-extreme fire weather. Mild, moderate and some extreme weather conditions yield intermediate-severity fire.

Eco-Vis DATA MAPPING AND MODEL VISUALIZATION: The Eco-Vis webtool facilitates real time exploration of the geography of fire refugia, and the drivers that support persistence

Eco-Vis: https://firerefugia-app.forestry.oregonstate.edu/projects/v3
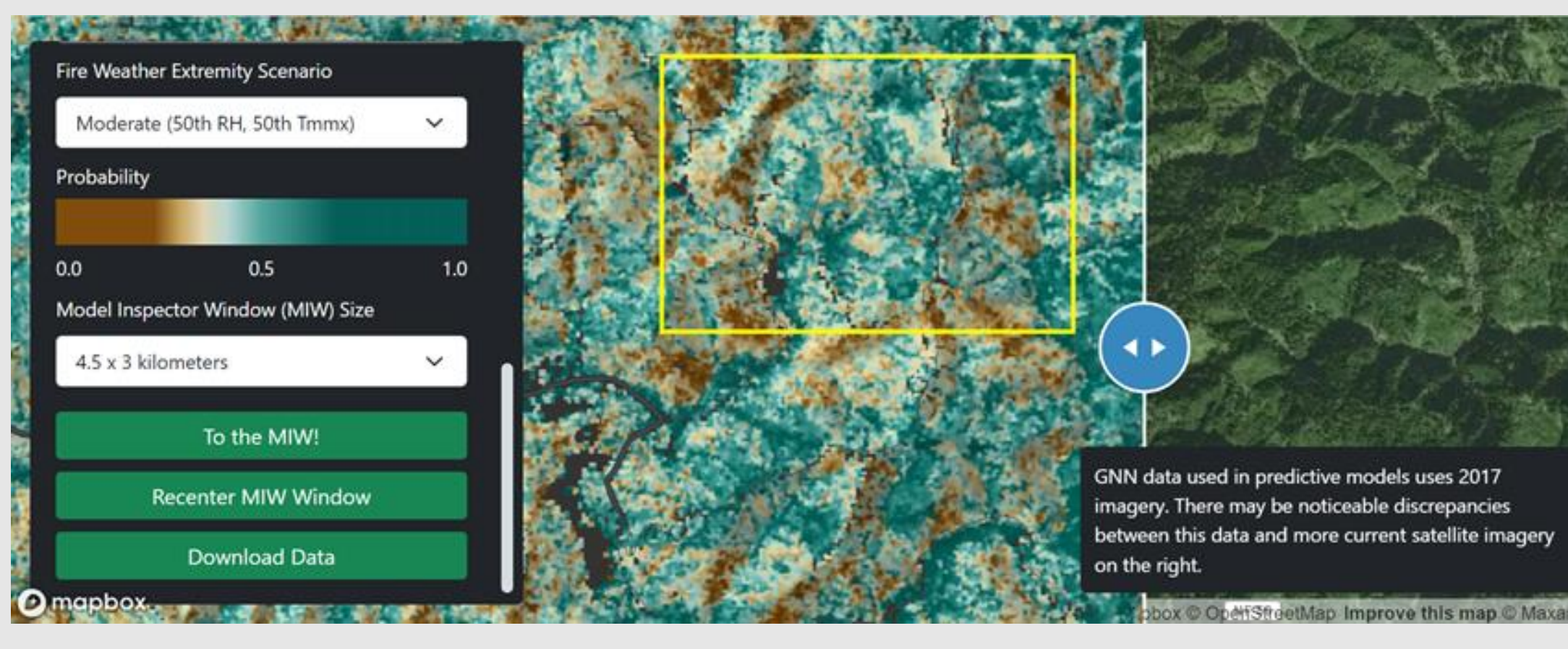
The fire refugia model suite aims to inform regional conservation planning efforts, project-level planning where mature and old forests and habitat for old-forest associated species are high priorities, and to facilitate critical discussions about the geography of fire, mature and old forests, and their coexistence, as fire activity accelerates with climate warming.

More here: https://firerefugia.forestry.oregonstate.edu/home

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Climate-smart stewardship of older forests
Combined Fire Refugia (Max)
Chapman and Davis 2022 (Old Forest Assessment Final Report)