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Modeling Ecosystem Service Trajectories and Forest Resilience in Olympic Experimental State Forest

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1. INTRODUCTION

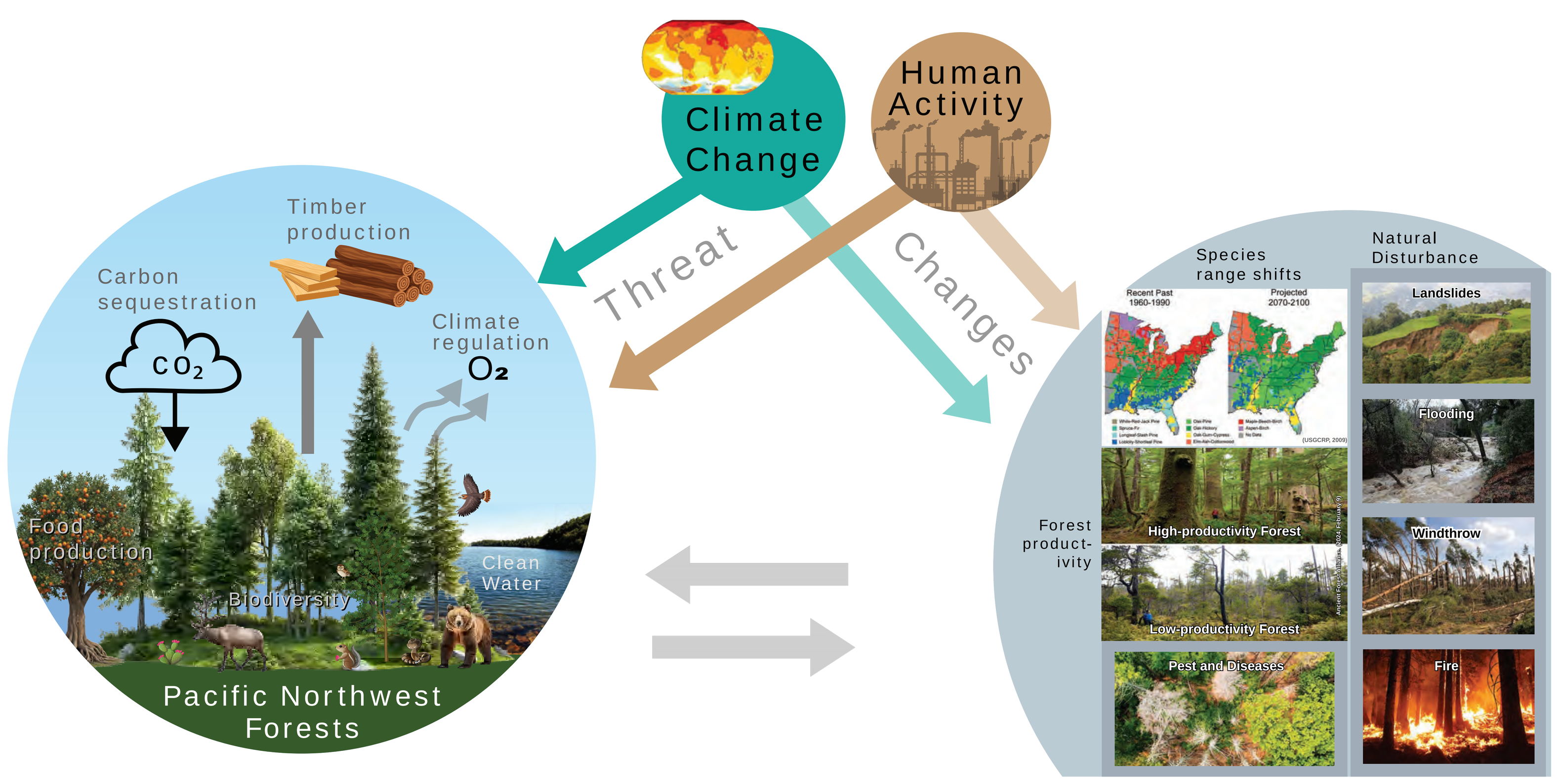


Figure 1. Ecological benefits, drivers, and consequences of change in Pacific Northwest Forests.

Objective:

- Quantify how landscape-scale management strategies influence long-term forest structure, ecosystem service provision, and landscape resilience
- Evaluate trade-offs among ecosystem services under increasing climate stress and interacting disturbance regimes

Study Area

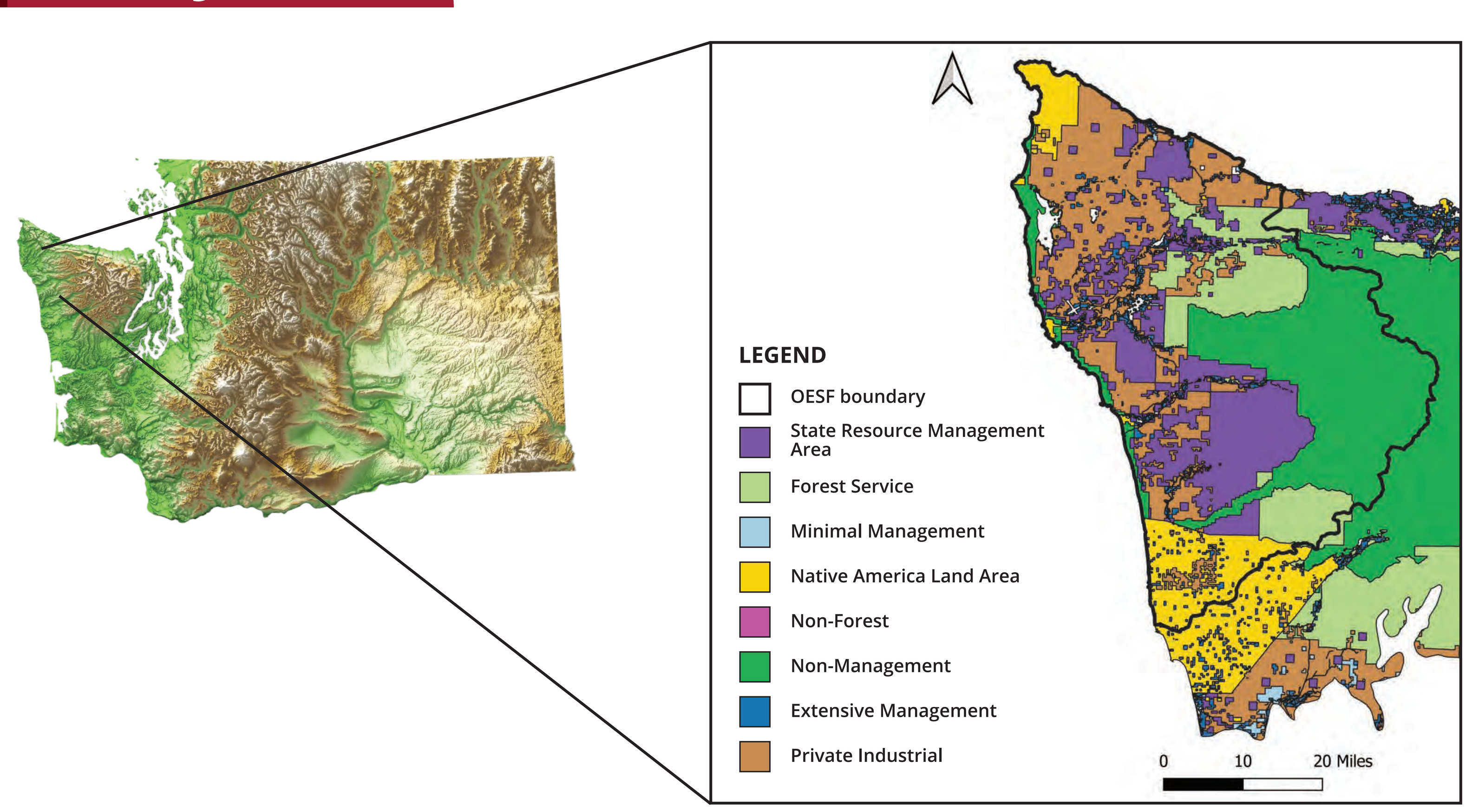


Figure 2. Map of Olympic Experimental State Forest (OESF) showing the land management

- 632,000 hectares.
- Dominated by western hemlock, Douglas- fir, Sitka spruce, and western redcedar.

2. MATERIALS AND METHODS

Modeling Framework:

LANDIS-II
Spatially explicit forest landscape model

- Spatial resolution: 90 m x 90 m
- Time step: 5 years
- Simulation period: 2025 - 2100

KEY EXTENSIONS

- Species succession (tree growth & mortality) - Net Ecosystem Carbon and Nitrogen (NECN).
- Management interventions - Biomass Harvest.
- Natural disturbances - Social- Climate Fire & Original wind (windstorms).

Management Strategies:

- We simulated a gradient of functional zoning strategies that vary the proportion of ecological preserves, intensively managed plantations, and ecological silviculture.

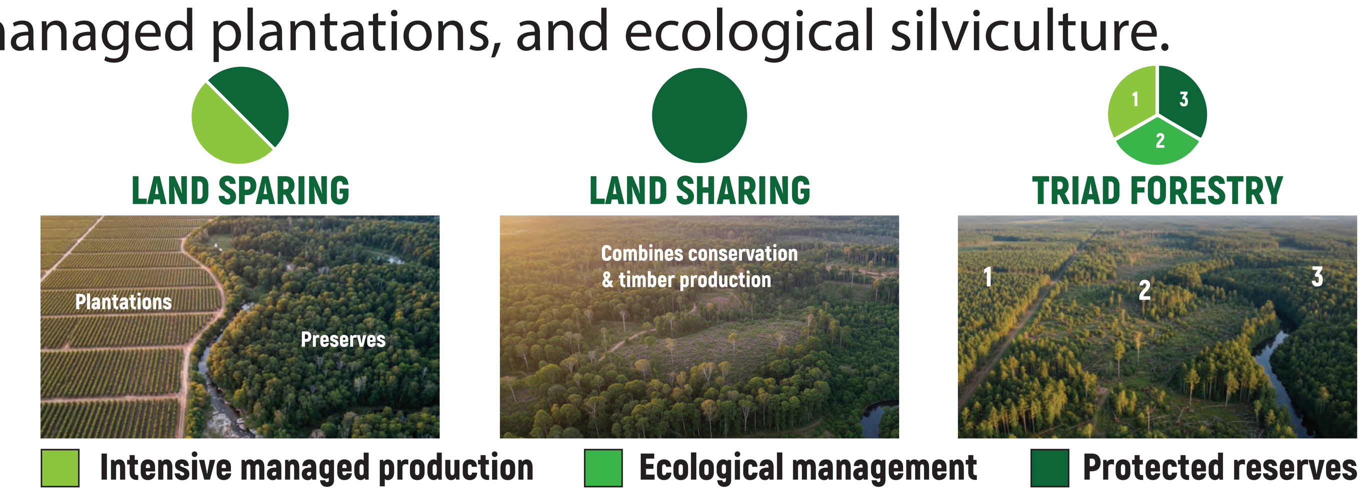
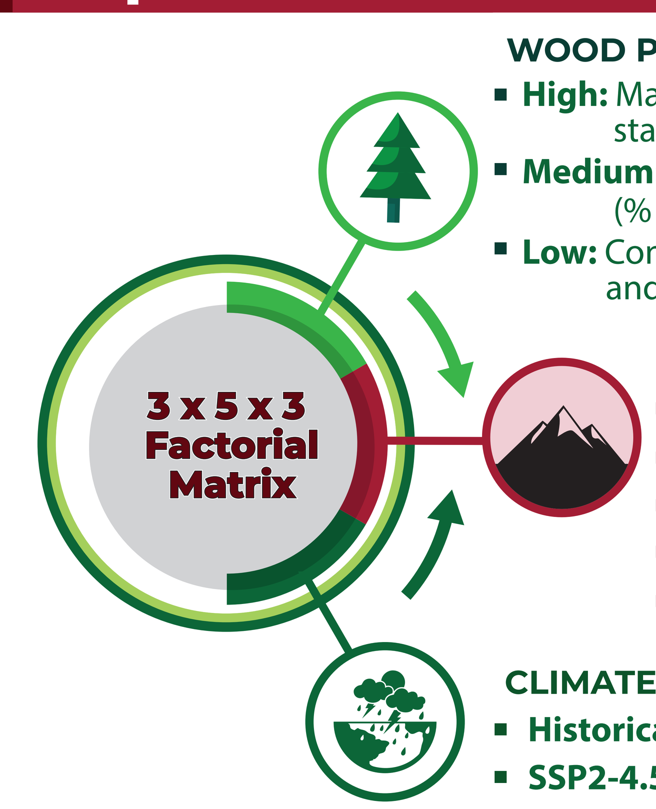


Figure 3. Conceptual illustration of functional zoning strategies across a landscape gradient

Experimental Design:



WOOD PRODUCTION GOALS

- **High:** Maximize wood production based on steady state maximum sustainable yield (MSY)
- **Medium:** Moderately conservative production levels (% of MSY based on risk factors)
- **Low:** Conservative yield (% of MSY based on risk factors and prioritizing other ecosystem functions)

LAND ZONING STRATEGIES

- **Sharing:** Uniform low-intesnity forestry
- **Triad1:** Emphasize ecological forestry
- **Triad2:** Emphasize timber production
- **Triad3:** Balanced distribution of functions
- **Sparing:** High-yield & high-conservation separation

CLIMATE SCENARIOS

- **Historical:** 1979 - 2024
- **SSP2-4.5:** Intermediate scenario; assumes mitigation
- **SSP5-8.5:** High emissions trajectory

ECOSYSTEM SERVICES ACCESSED

- **CARBON STORAGE:** Total ecosystem carbon (Mg C ha^{-1})
- **BIODIVERSITY:** Shannon diversity index, structural diversity, late-succesional habitat
- **TIMBER PRODUCTION:** Merchantable volume (m^{-3} ha^{-1})

3. ANALYSIS APPROACH

Trade-offs and Synergies:

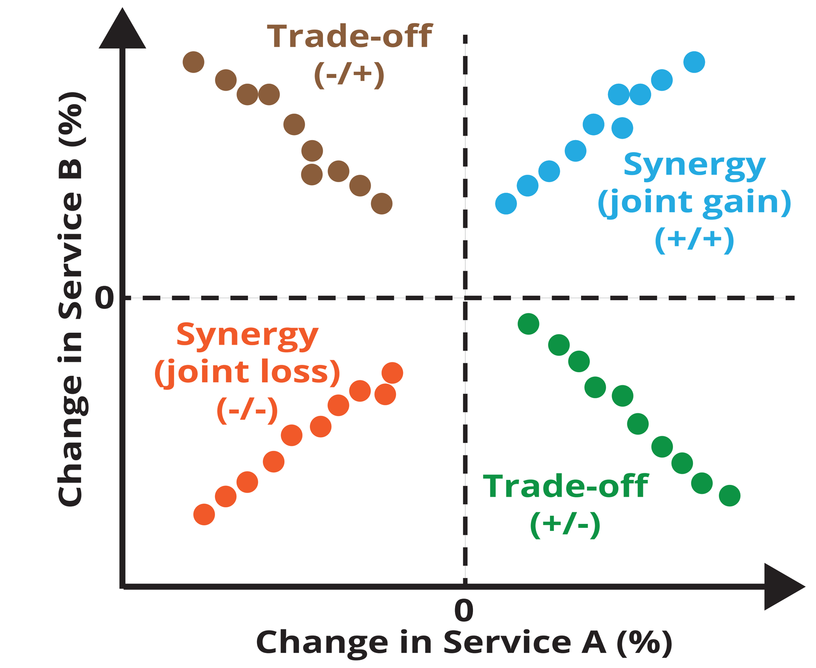


Figure 4: Conceptual trade-offs and synergies between ecosystem services, shown as relative changes in service A and B from baseline conditions (Bennett et al., 2009; Raudsepp-Hearne et al., 2010).

Resilience Concept:

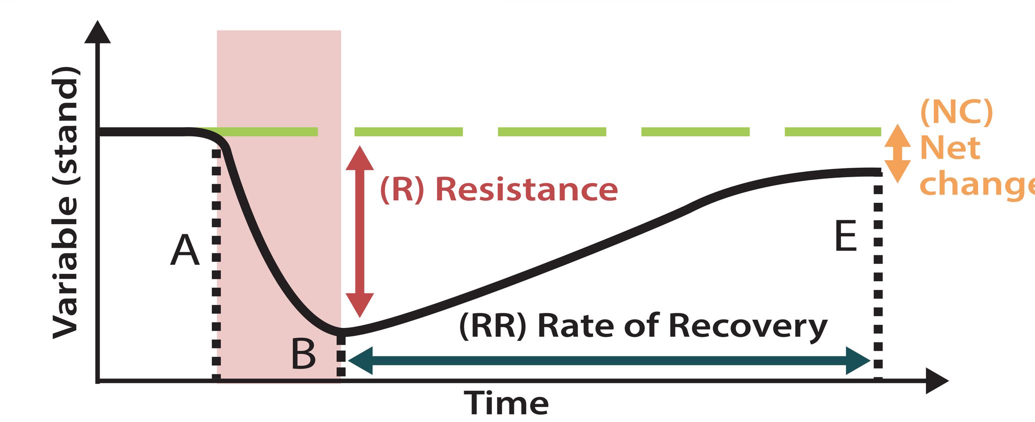


Figure 5: Conceptual framework for measuring forest resilience. Adapted from Hardy et al. (2025)

Where: **A** -Pre-disturbance, **B** -Post-disturbance, and **E** -End of simulation. These points quantify three key metrics: **Resistance** (R = B/A), ability to withstand disturbance. **Rate of Recovery (RR)**, speed of return toward baseline. **Net Change (NC = E/A)**, long-term difference in ecosystem service provision compared to pre-disturbance levels.

4. EXPECTED OUTCOME

- Climate stress will amplify divergence among management strategies via altered disturbance regimes.
- Simulations will quantify carbon, biodiversity, and timber trajectories, revealing trade-offs and synergies.
- Management strategies will differ in resistance and recovery, with triad forestry expected to enhance overall resilience.

References

5. ACKNOWLEDGEMENT

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- SILVER lab, Washington State University, WA
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