Tree regrowth impacts on high-resolution (1-m) snowpack modeling: A proof of concept in a Mediterranean montane catchment

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BACKGROUND AND RESEARCH QUESTIONS

- Spatially heterogenous forests require high resolution snow models to **quantify the impact of forest cover on snowpack dynamics due counteracting processes**: snow interception, solar shading, increased longwave radiation, wind sheltering, and snow redistribution.
- Modelling studies have assessed the impact of **forest practices (e.g., thinning and clearcutting)** on snow accumulation and melt; however, these have typically **ignored tree regrowth and its impact on the snowpack** ⇨ Required to assess **long-term impact of forest disturbance practices on the snowpack**.

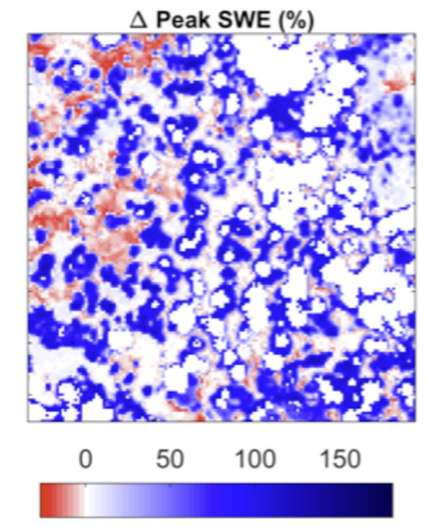
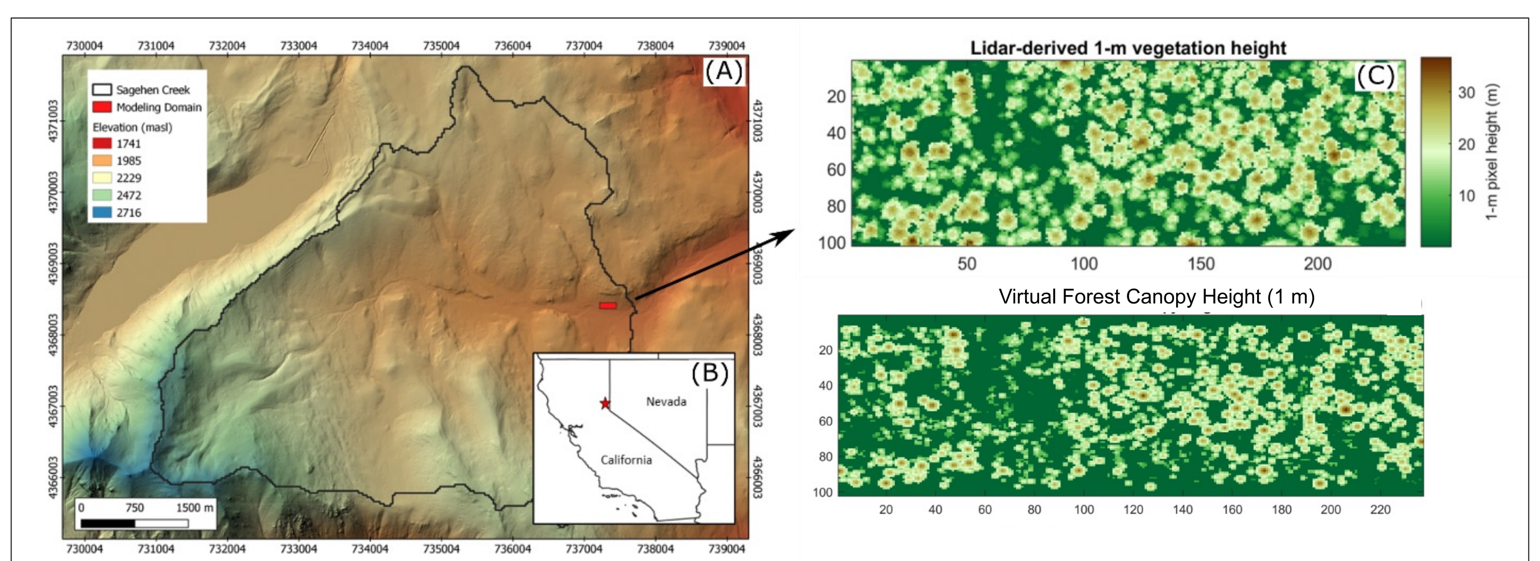


Fig. 1: Change in peak SWE following forest thinning (Krogh et al., 2020)

1. What is the impact of including tree regrowth feedbacks on high-resolution (1-m) snowpack simulations following forest intervention?
2. Does it matter when we intervene the forest in terms of tree regrowth rates and its feedbacks on snow accumulation and melt?

STUDY SITE AND METHODS



Site characteristics:

Sagehen Creek Field Station (UC Berkley and US Forest Service), Sierra Nevada, CA

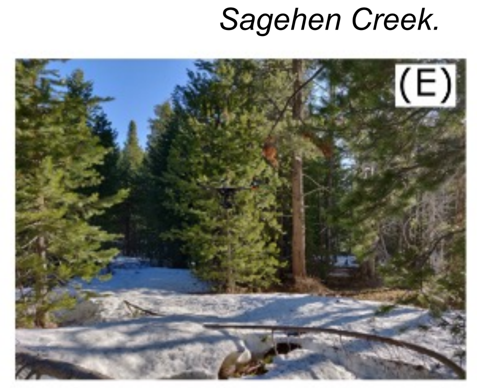
Small, low-elevation, forested rectangular domain (84 m x 234 m)

Long term observational record

Multi-temporal, lidar-based canopy height model (1 m)

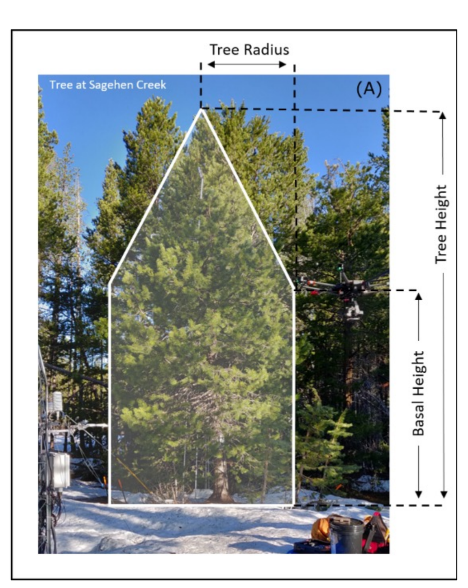
Study period: 1980-2020

(right) Characteristic forest patch highlighting thinning practices in Sagehen Creek.



(left) Characteristic snow accumulation and melt spatial variability in the Sierra Nevada.

Virtual forest: lidar-based allometric relationships



Modeling Scenarios:

- Control simulation ➟ Virtual forest based on 2014 USFS lidar flight.
- 20-m forest thinning ➟ Trees below 20-m height are removed
- Clearcutting ➟ All trees are removed

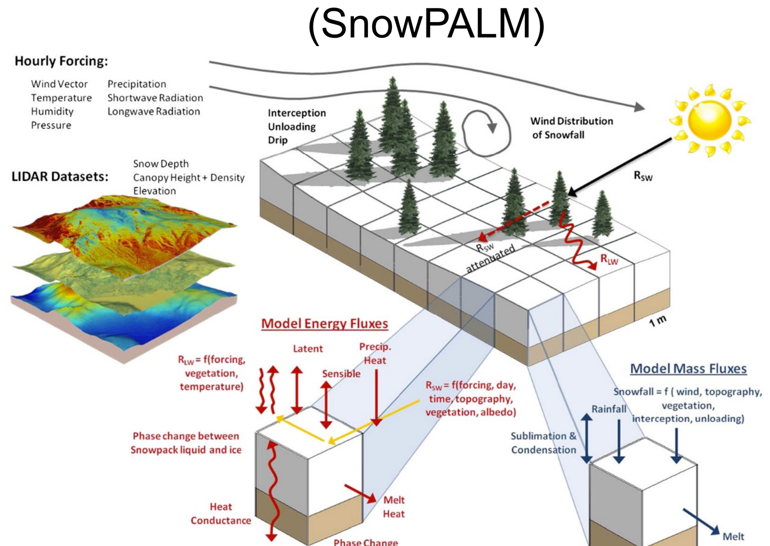
Scenario	Mean tree height (m)	Mean tree cover
Historical	16.1	0.41
20-m forest thinning	7.6	0.29
Clearcutting	0.5	0.03

We assess the impact of when the forest is intervened and its climate by **lagging and stacking years** over the 40-yr period, for example:
Climate Lag$_{20}$ = [year$_{21}$:year$_{40}$] + [year$_{1}$:year$_{20}$]

Modeling configuration:

- Offline coupling between SnowPALM and RHESSys.
- SnowPALM: High-resolution snow modeling. Tree's spatial variability explicitly included.
- RHESSys: carbon + water + energy cycling
- RHESSys provides changes to carbon allocation (used to grow trees) and SnowPALM provides snowmelt inputs back to RHESSys (annual feedback).

Snow Physics and Lidar Mapping (SnowPALM)



Broxton et al. 2015

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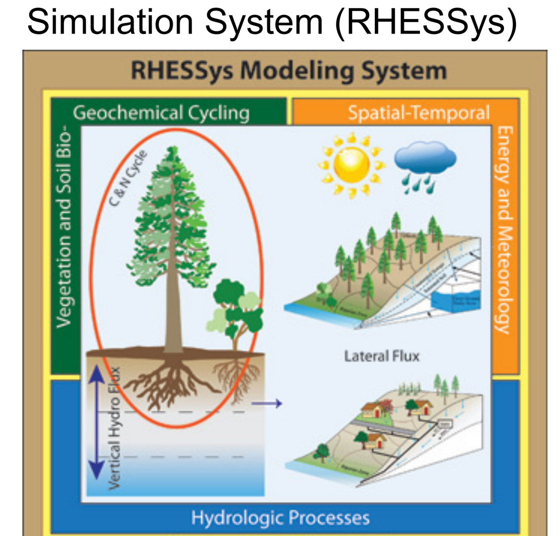
The Regional Hydro-Ecological Simulation System (RHESSys)



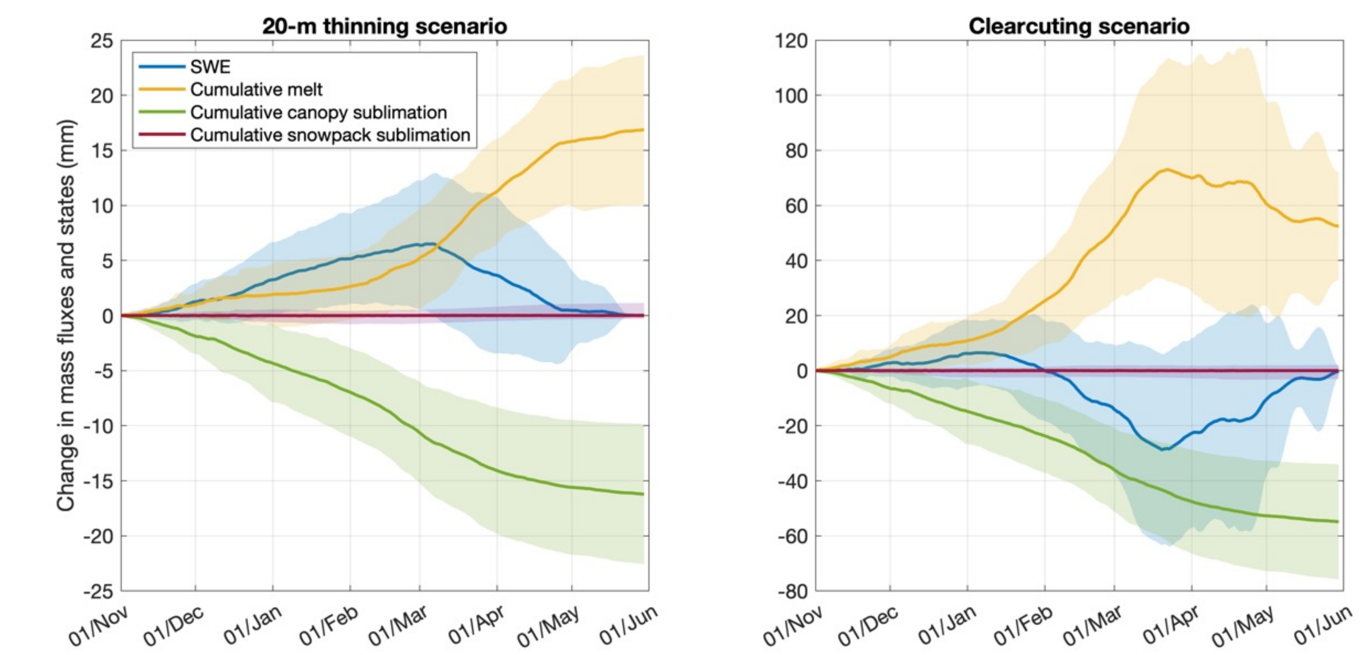
Tague and Band (2004)

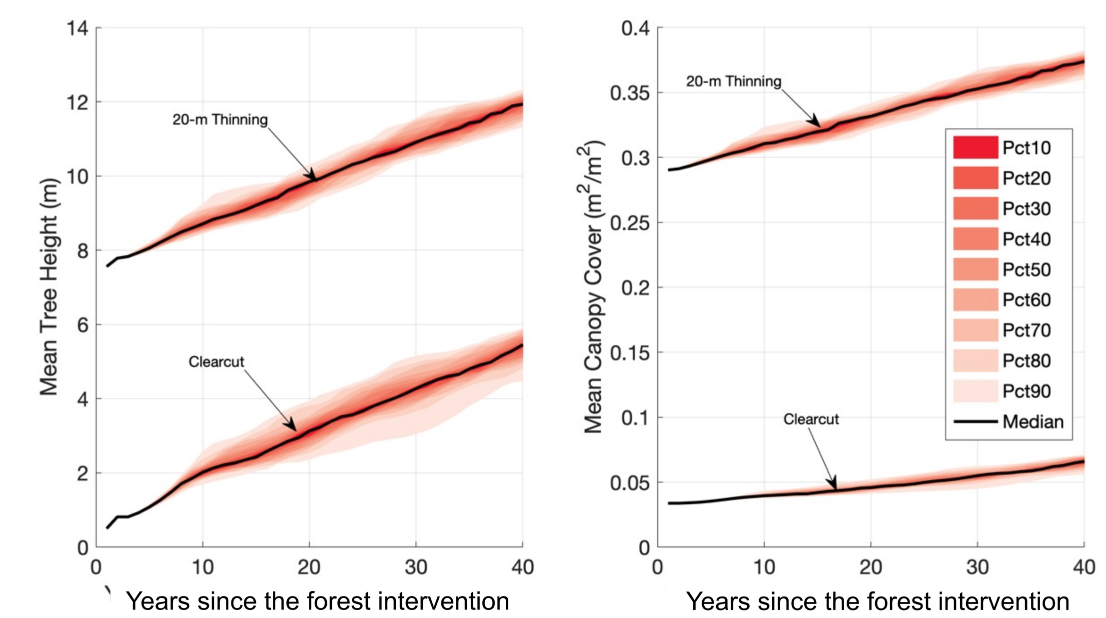
RESULTS

Baseline: Impact of forest disturbance as simulated by SnowPALM (standalone – without tree regrowth)

Variable (Disturbance - historical)	20-m thinning	clearcutting
Δ Peak SWE	7.5	2.4
Δ Annual melt (mm)	15.1	49.8
Δ Annual canopy sublimation (mm)	-15.1	-51.7
Δ Annual snowpack sublimation (mm)	0.5	-0.3

Forest disturbance increases snow accumulation and melt through decreasing canopy sublimation

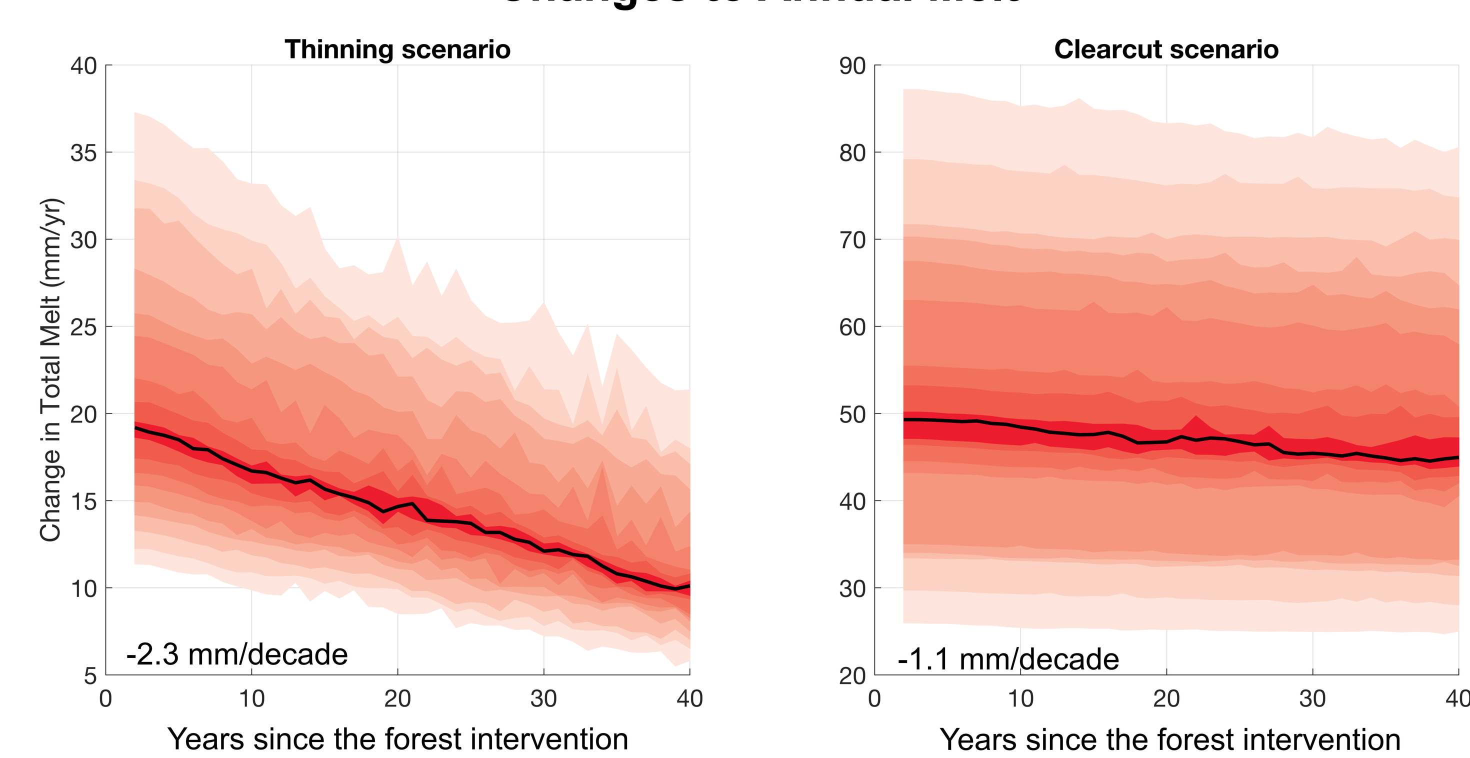




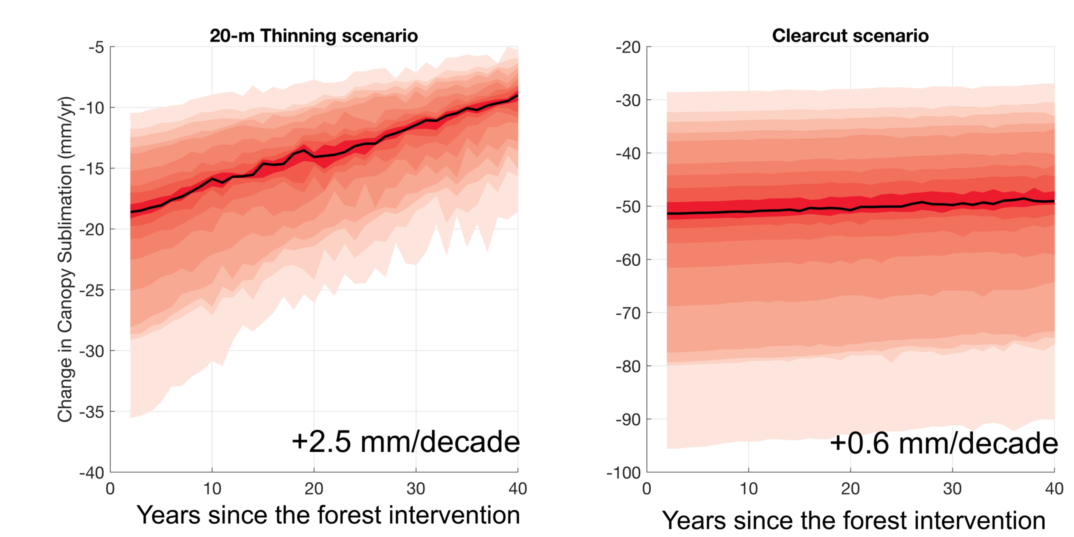
Tree regrowth

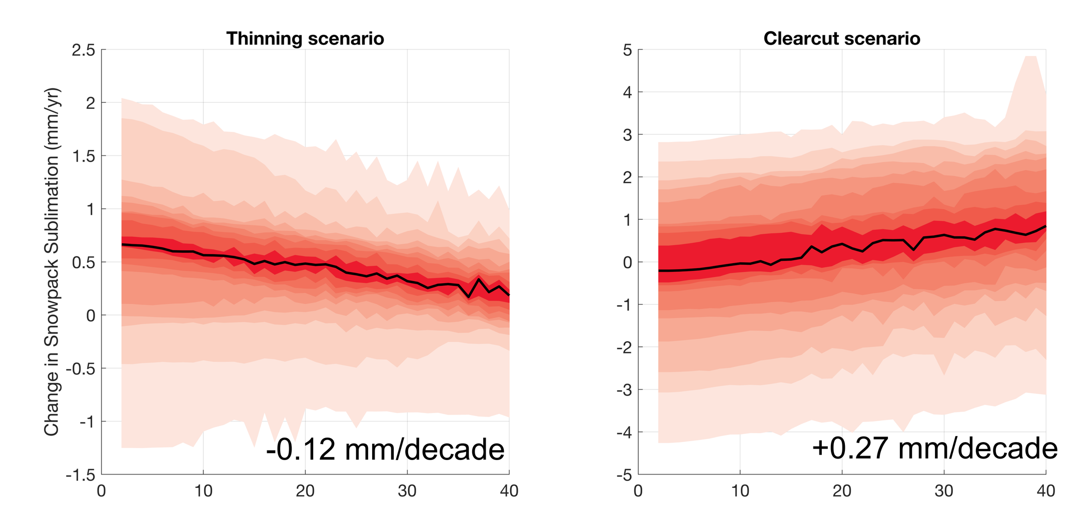
- When the forest is intervened does significantly affect the rate of regrowth, particularly in the clearcutting scenario.
- 20-m thinning: ~0.5 m/decade
- Clearcutting: ~0.75 m/decade
- Less competition and more water and energy available in the clearcutting scenario produce 50% faster growth rates

Changes to Annual Melt



Changes to canopy sublimation & snowpack sublimation





- On average, **half of the snowmelt benefits from forest thinning disappear** after the 40-yr period, in contrast to those from clearcutting that decrease slightly.
- In the thinning scenario, **increasing canopy sublimation following tree growth controls changes** to snow accumulation and melt.

CONCLUSIONS

➟ Effect of the tree regrowth on snowpack dynamics is important, particularly in a thinning scenario; **as trees grow, they intercept and sublimate more snow reducing snow accumulation and melt volumes**.

➟ **Forest thinning produces more moderate changes to melt volumes** compared to clearcutting; however, when thinning, the benefits seems to be reduced faster compared to the clearcutting scenario.

➟ It necessary to **move towards more integrated modelling frameworks** that benefits from advances in the snow and ecological community to more explicitly represent the feedback between growing trees and water.

➟ Caution about the **representation of trees regrowth**, particularly its **spatial arrangement** > this can have an important effect on snowpack dynamics.