Why subsurface features matter for managing forests, water and fire in the face of increasing drought frequency and severity

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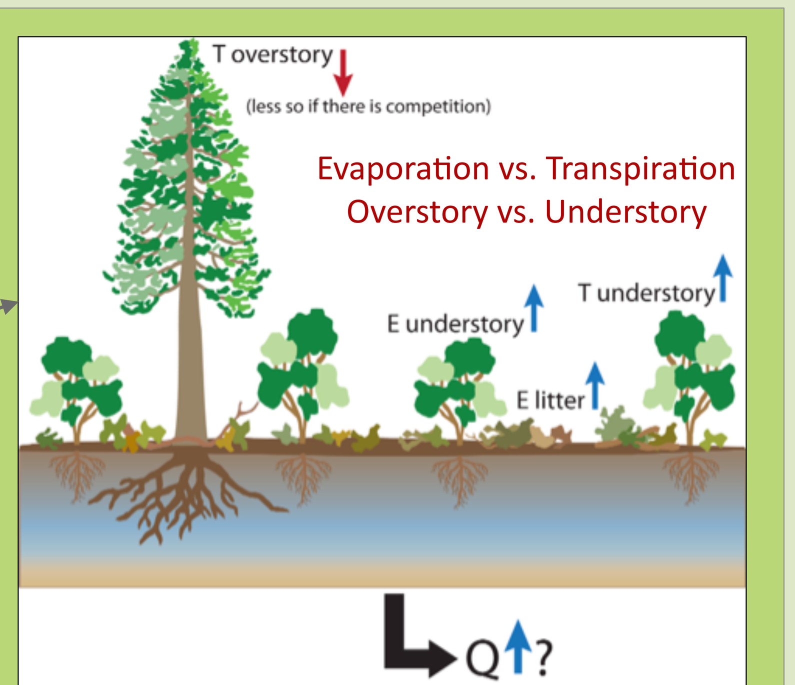
Introduction

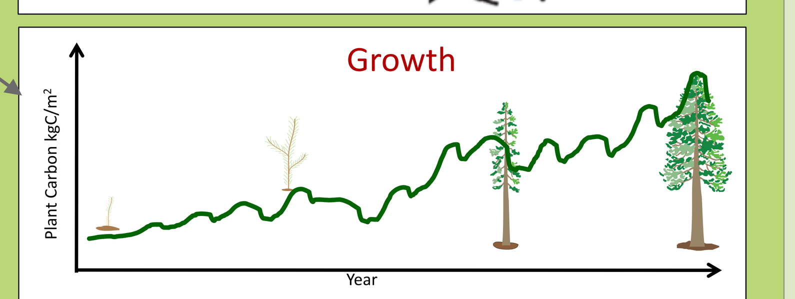
- Droughts, fires and human-driven density reduction are interrelated disturbances in semi-arid forests
- Forest vulnerability to these disturbances depends on interactions between forest structure (above ground biomass and root distributions) and water availability
- Wildfire and fuel treatments alter forest evapotranspiration and runoff production, and this often has implications for streamflow and water resources
- Measurements of water flux in thinned forests, or following mortality, show both increases and decreases in stand to watershed scale evapotranspiration (e.g. Biederman et al., 2015; Adams et al., 2011; Clark et al., 2016)
- Post-disturbance responses also vary with time as forests recover
- Coupled models of ecosystem hydrology and carbon cycling are tools that can help researchers understand these complex time varying interactions, and assist managers planning directed at:
  - reducing fire risk
  - maintaining ecosystem health
  - carbon storage
  - regulating water resources

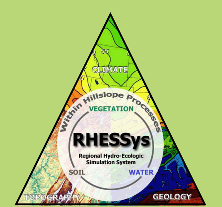
Research Questions (RQ)

1. How do changes in forest structure (through fuel treatments or mortality) alter forest water use?
2. Does water availability for the remaining trees influence subsequent vulnerability to drought?

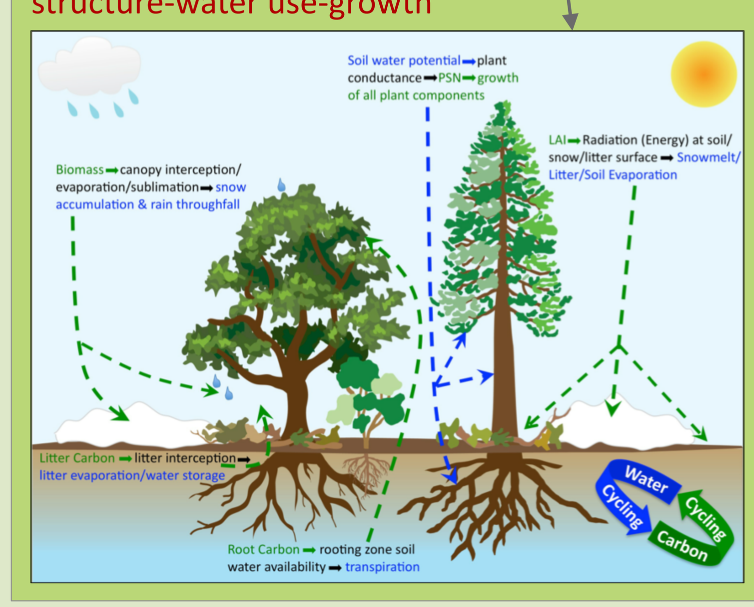
Our Modeling Approach:
Regional Hydro-Ecologic Simulation System (RHESSys)
This model utilizes state-of-the art computing to develop integrated modeling tools, workflows, documentation, and visualization that support data assimilation, collaborative model development, and usage by a broader research community – and captures key processes needed for RQ's



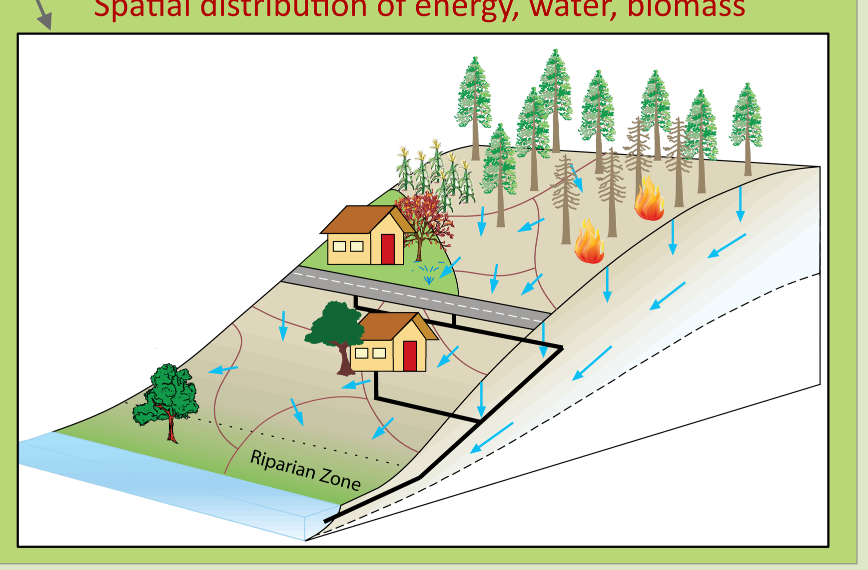




Fully Coupled between canopy structure-water use-growth



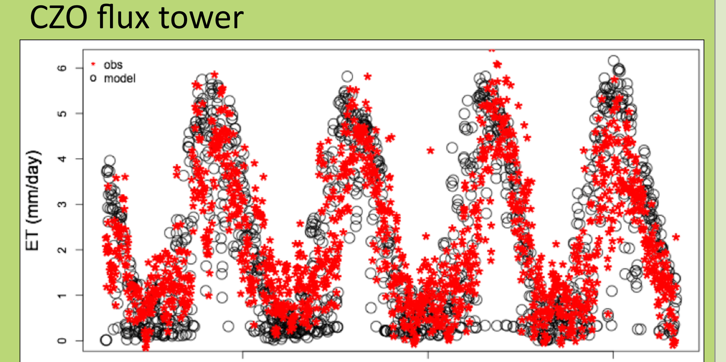
Spatial distribution of energy, water, biomass



Study Site: California Sierra

Model Performance

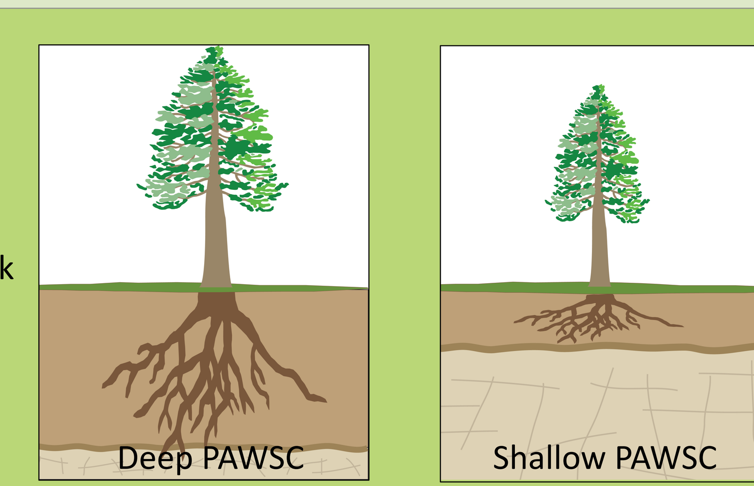
Modeled and observed estimates of ET at CZO flux tower



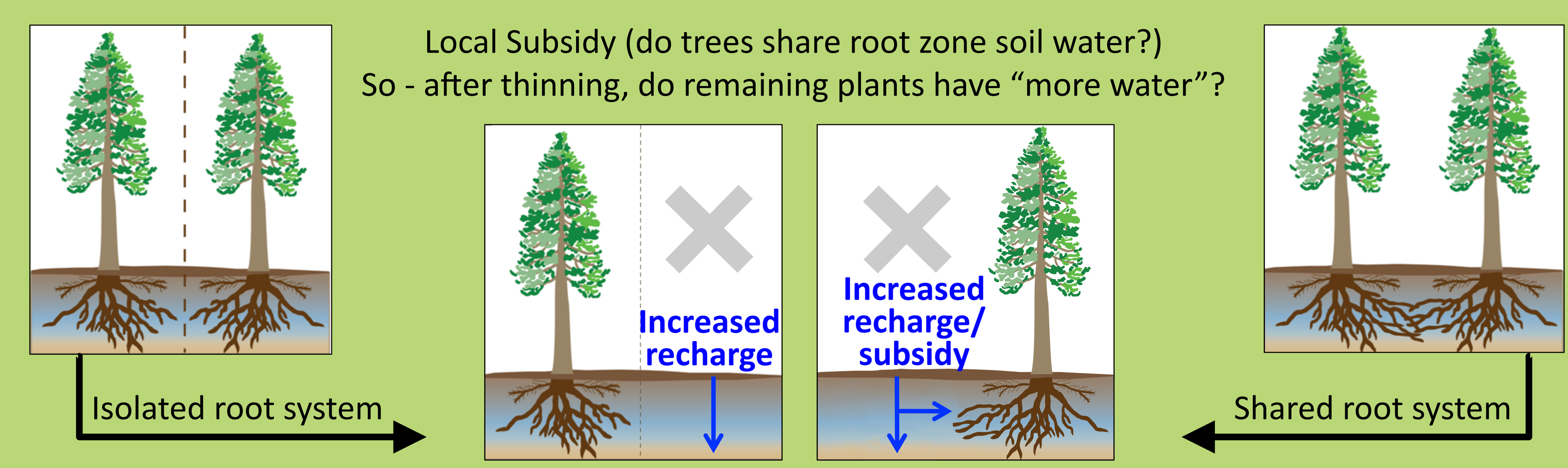
Model Experiment Design

A. Plant accessible water storage capacity (PAWSC) – Shallow vs. Deep

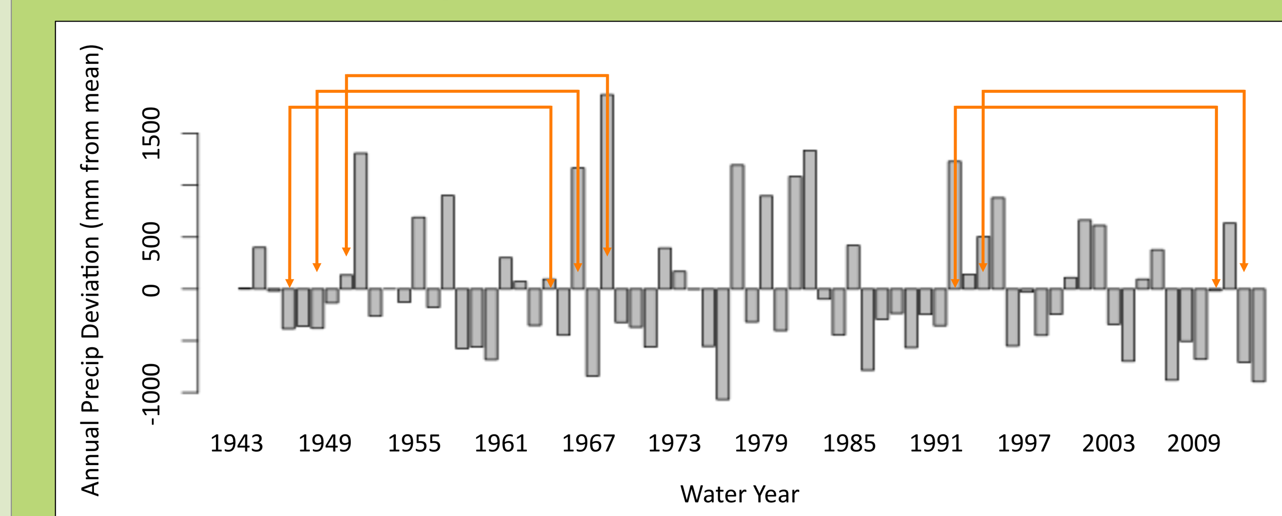
The amount of water that can be stored in the soil/saprolite/bedrock fractures that plant roots can access. PAWSC is a *capacity* – a maximum storage, which may or may not be filled depending on infiltration, drainage and ET.



B. Shared vs Isolated Root Systems



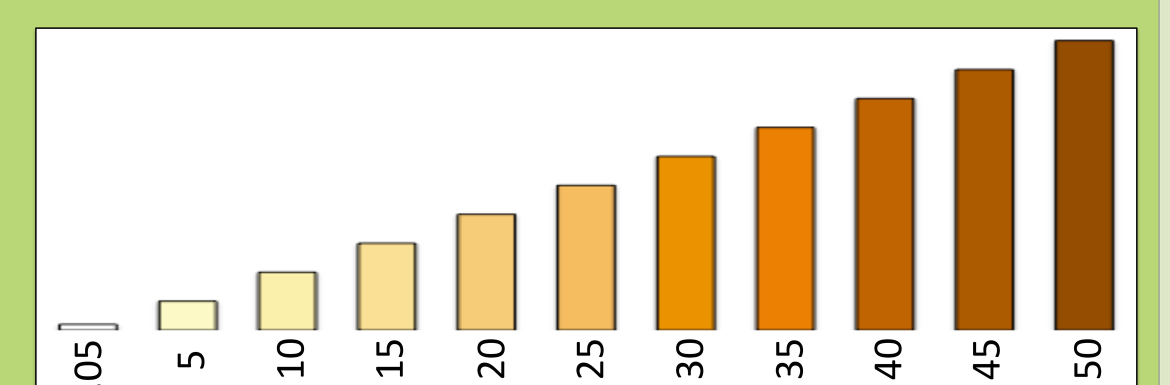
C. Climate and Recovery



Fuel treatment:
50 start dates
+ 20 Year Recovery

D. Thinning Intensity

10 scenarios of % biomass removal



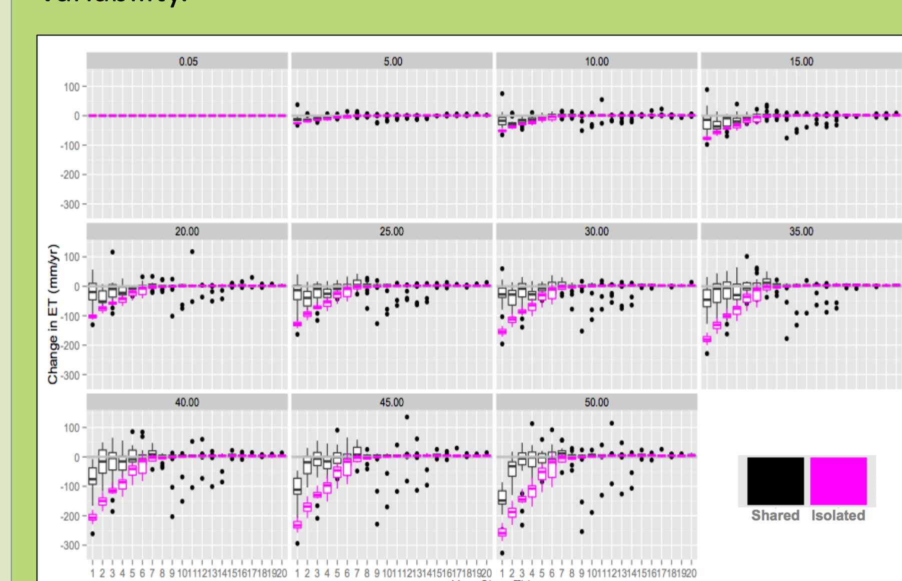
Results

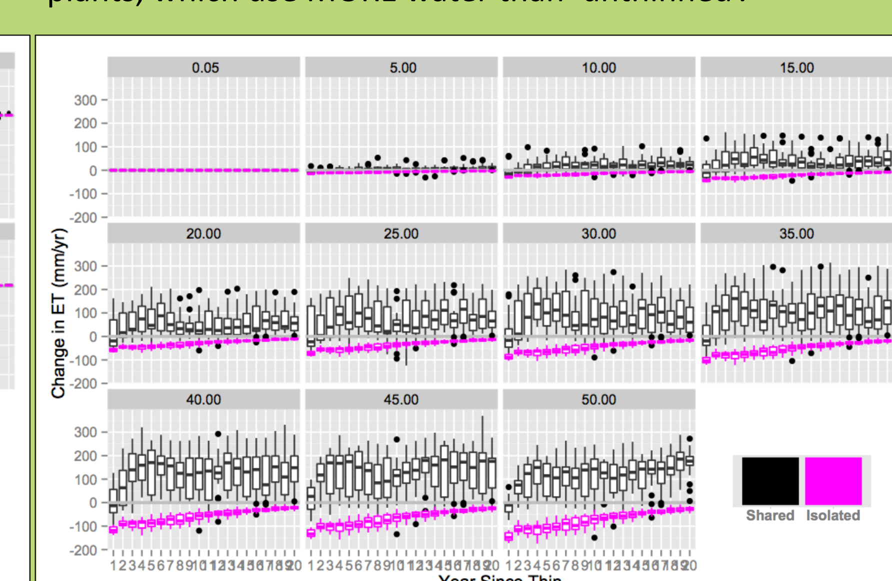
Deep PAWSC: Post thinning recovery of water flux

ET recovery depends mostly on whether or not remaining trees share water (Shared vs. Isolated) – subsurface is greater than effect of inter-annual climate variability.

Shallow PAWSC: Post thinning recovery of water flux

Thinning supports greater production and water use in remaining plants - if water is shared.
If roots share water, additional growth in remaining plants, which use MORE water than 'unthinned'.



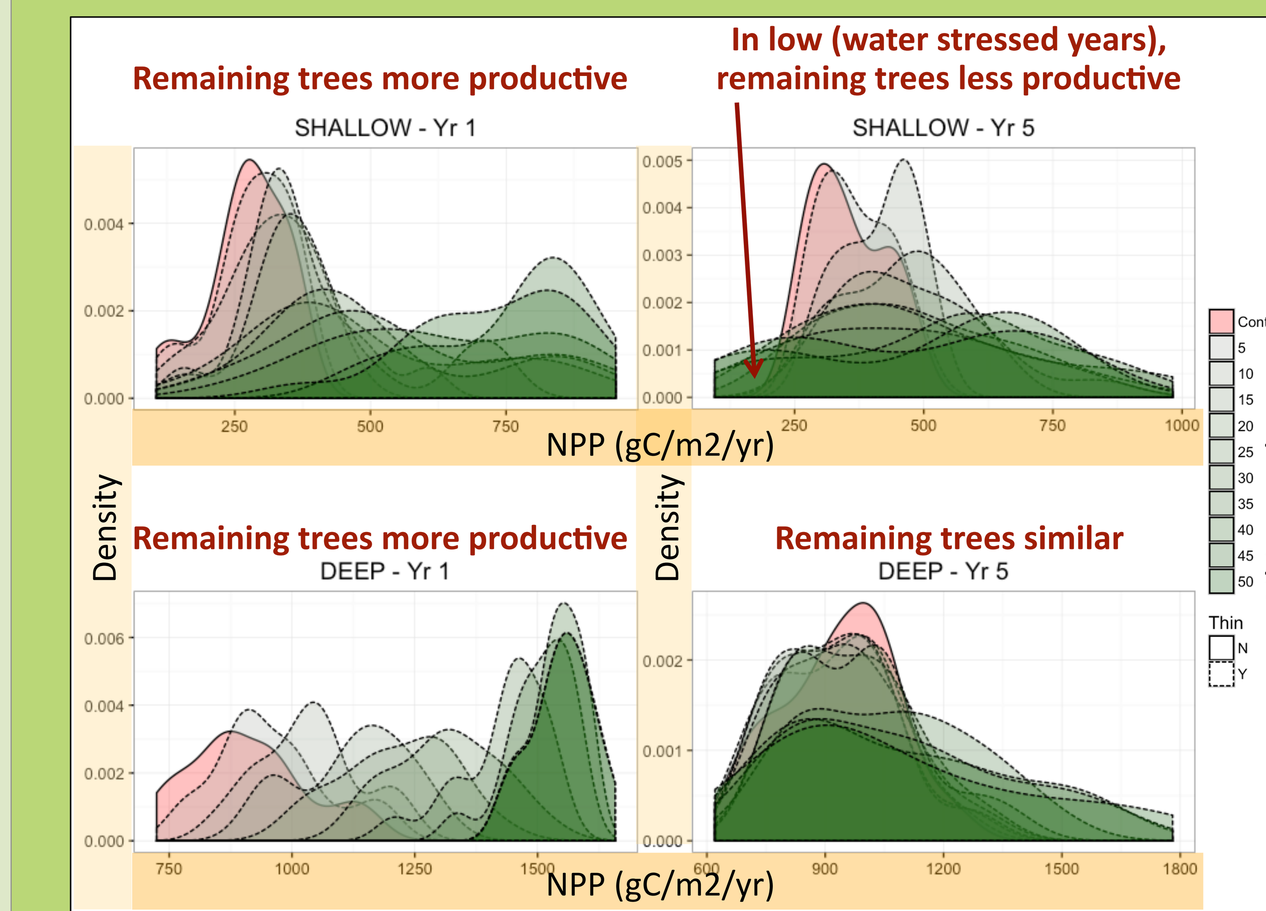


Box plots indicate variation across climate scenarios.
Each panel indicates a different level of thinning intensity (biomass removal %)

Post-disturbance productivity

In first year after thinning, indices of drought risk (NPP, NSC (not shown) are less in remaining trees

After 5 years however in deep soils, NPP similar, in shallow sometimes the increased growth leads to greater drought stress (potential fire risk)



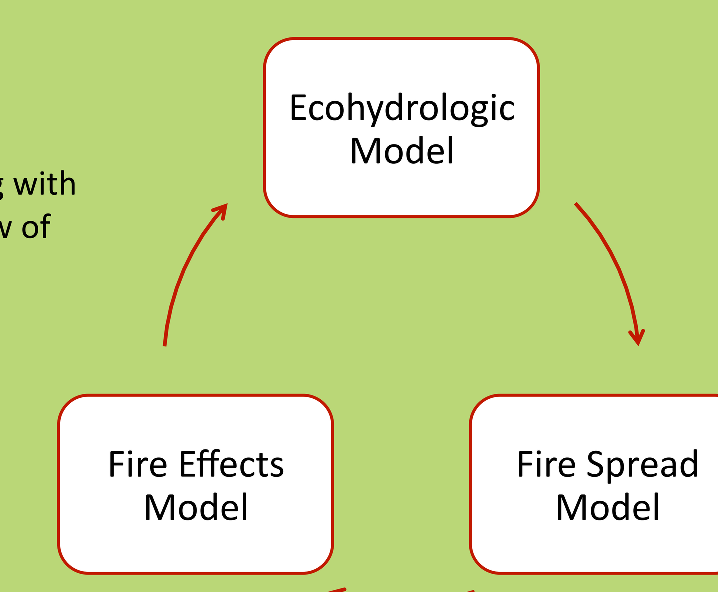
Conclusions

- Stand scale forest water use is in general likely to increase when disturbances (like density reduction or mortality) reduce biomass – but only initially
- Particularly if soil storage is small, stimulated regrowth of neighboring trees might increase water use (relative to pre-disturbance) AND increase drought stress vulnerability (lower NPP and greater NSC loss)
- Two critical parameters for estimating eco-hydrologic responses to changes in vegetation structure are: (1) plant available subsurface storage capacity and (2) the extent to which neighboring trees share water – these vary in space – We need techniques to improve estimates

Next Steps

1) Estimating shared water by vegetation requires collaborating with experimental design (e.g. sapflow of thinned trees) (Klein et al.)

2) Address effectiveness of density reduction in fully fire-spread-fire effect model



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