EPA United States Environmental Protection Agency

Climate-induced tree growth decline and mortality in Oregon

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Office of Research and Development
Pacific Ecological Services Division

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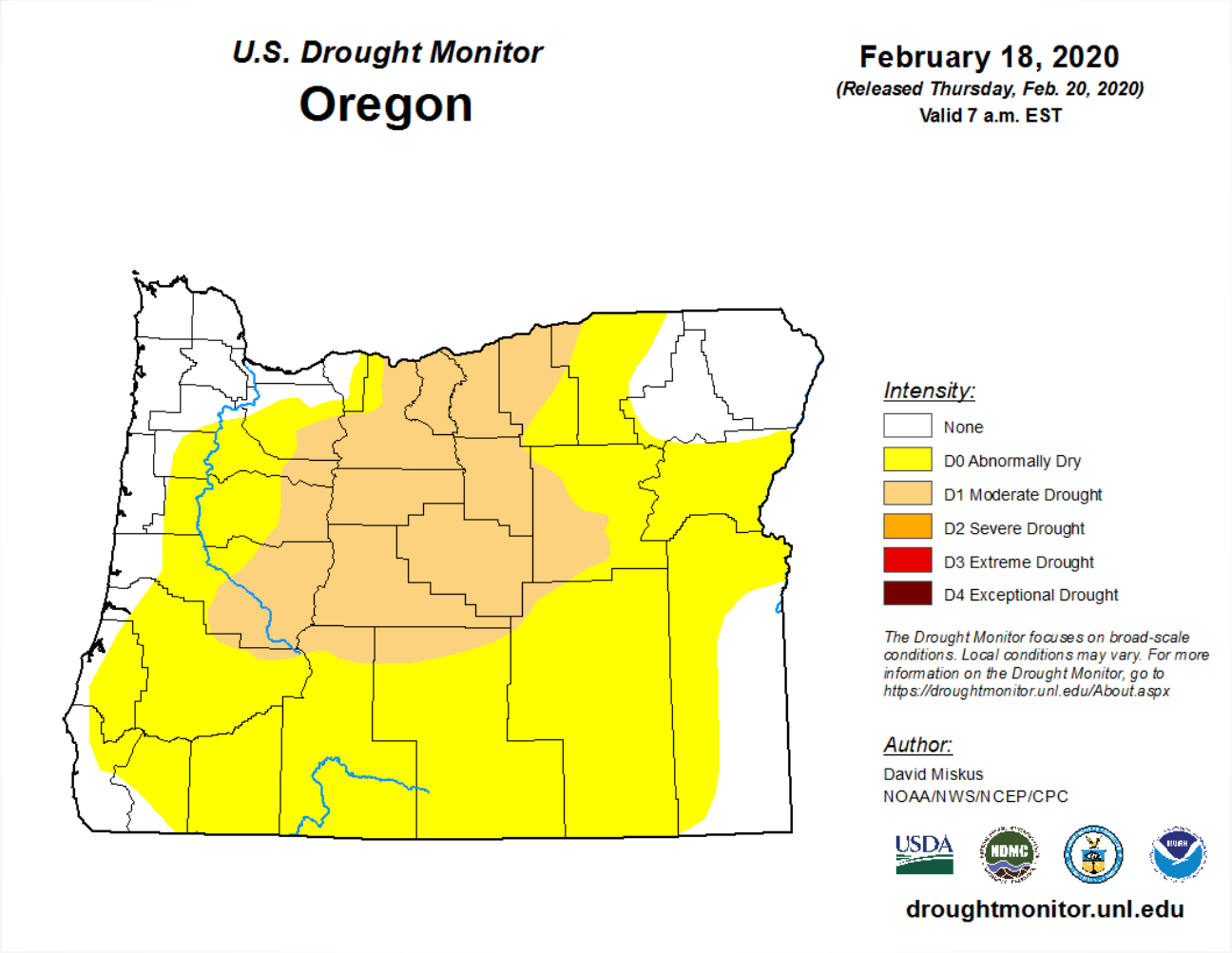
Background

- The frequency and scale of drought-related tree mortality events in western U.S. forests have increased in recent decades (Buotte et al. 2019).
- The 2012-2016 drought in California is estimated to have caused the demise of 129 million trees (USDA Forest Service 2017).
- Drought-induced tree mortality rates have increased but are still relatively low <1%/yr in Oregon and Washington (Reilly and Spies 2016).
- Progressively increasing temperatures and seasonal shifts causing reductions in snowpack and low summer stream flows in Oregon (Mote et al. 2019) suggest tree mortality in California could foreshadow future events in Oregon forests.

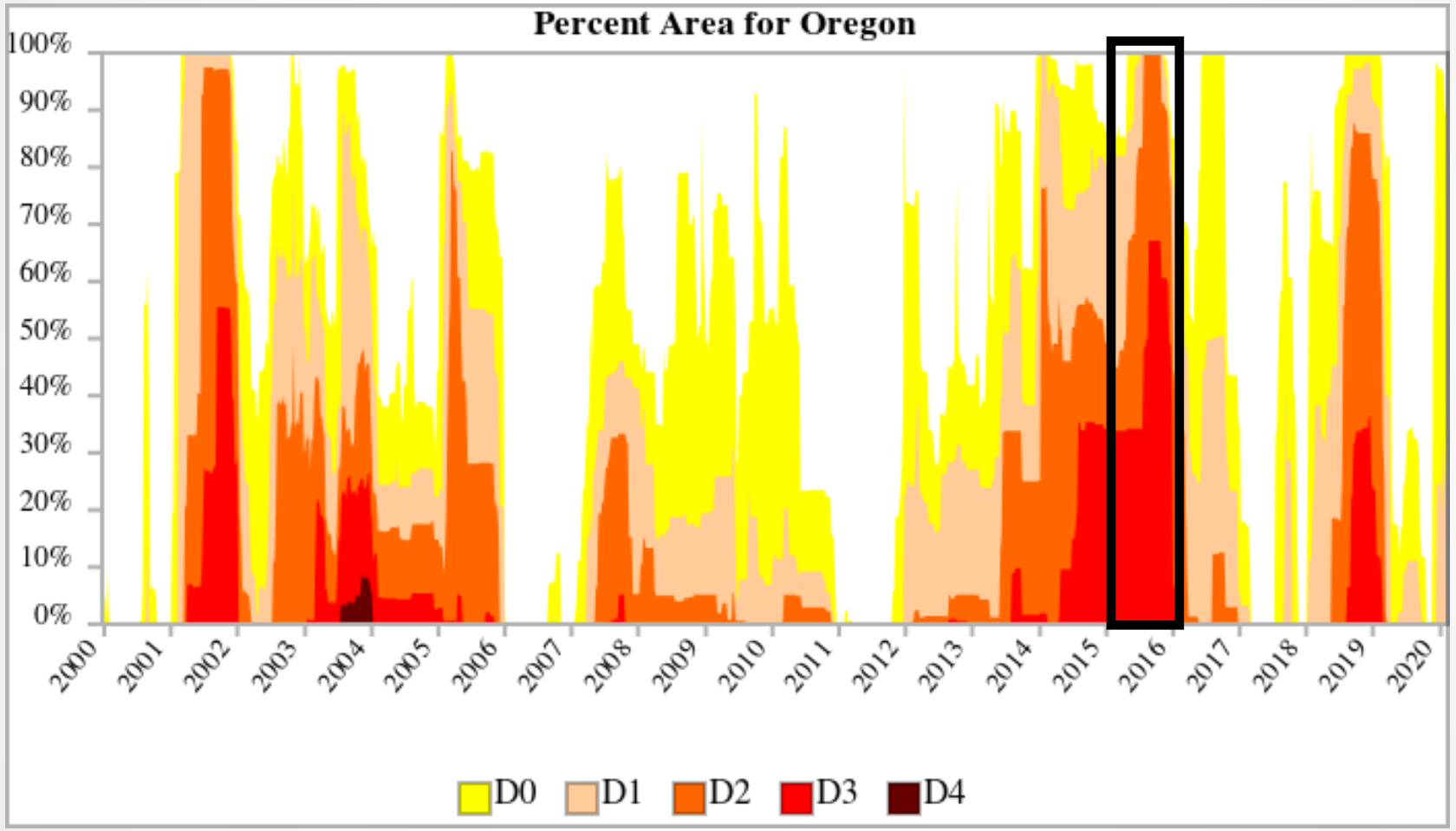


Current Drought in Oregon



https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?OR

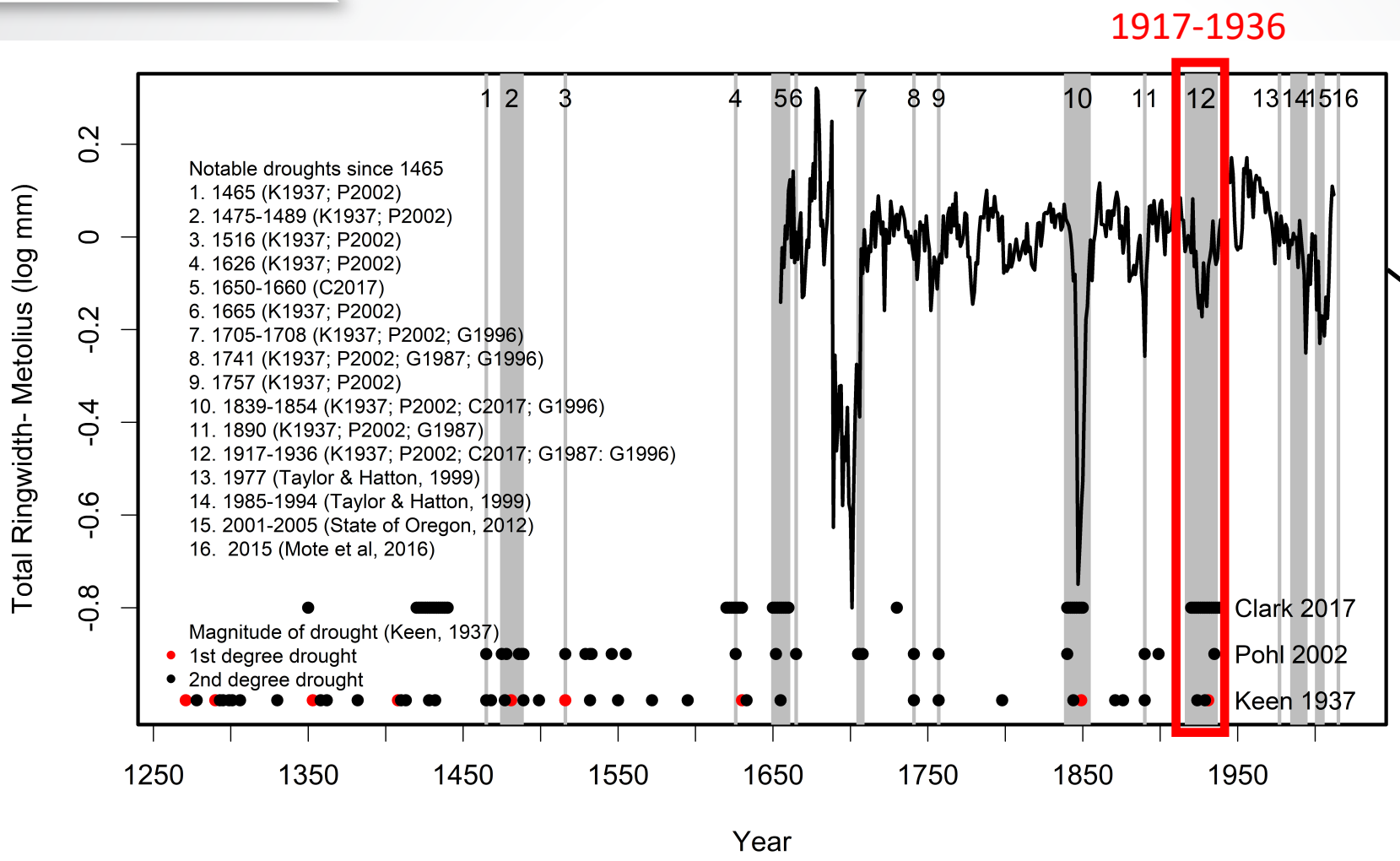
Drought in Oregon 2000-2020



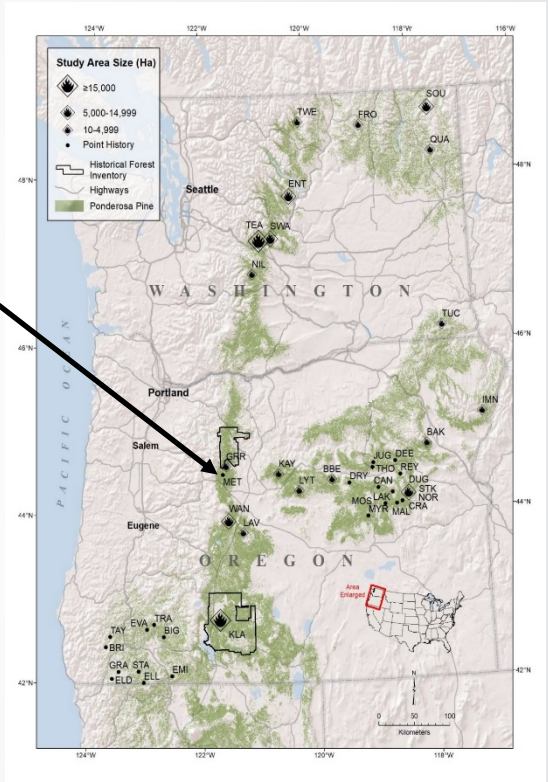
Snow drought in 2015 was unprecedented (Mote et al 2016).

https://www.drought.gov/drought/states/oregon

Reconstruction of drought history in Oregon

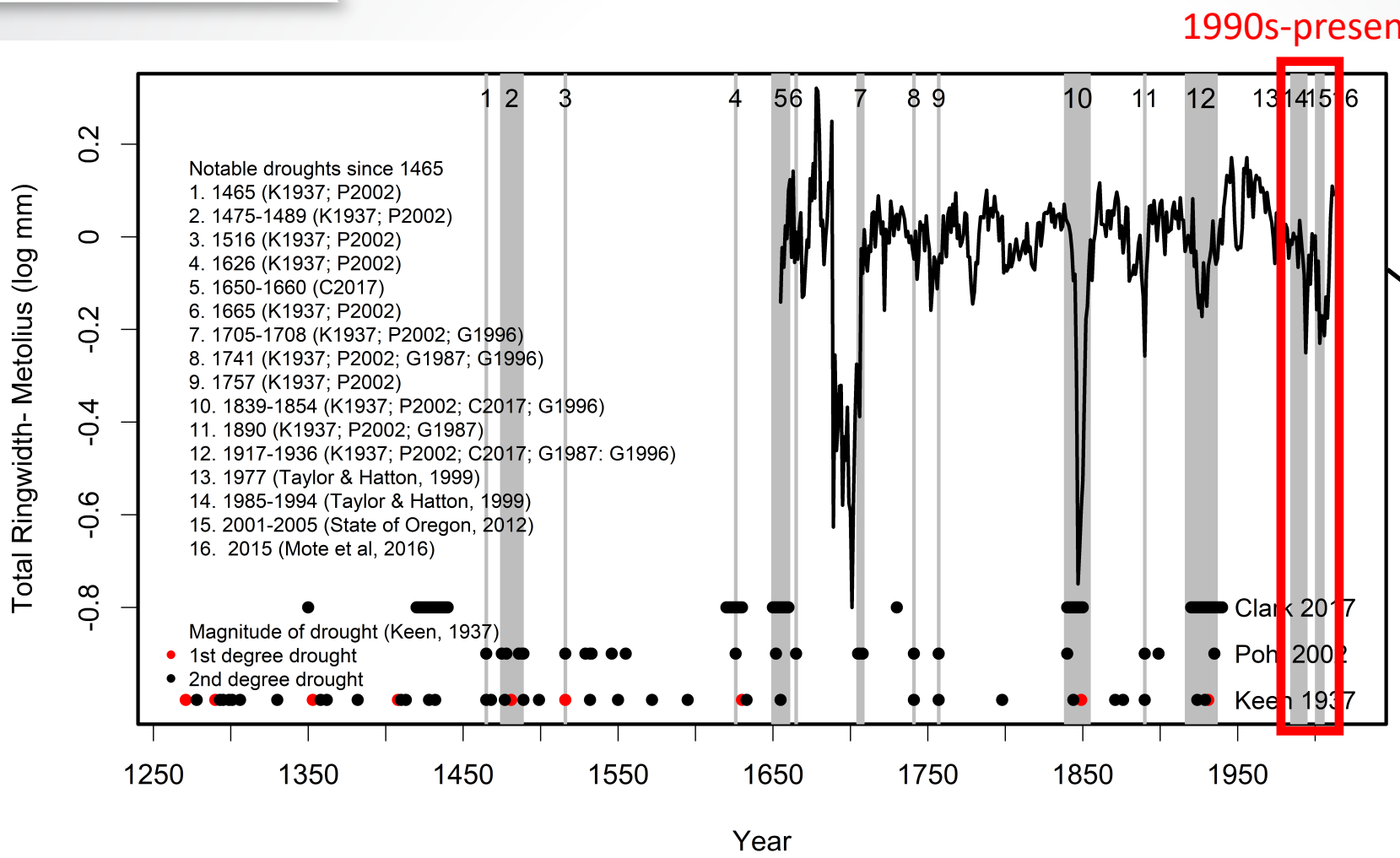


Ponderosa pine range

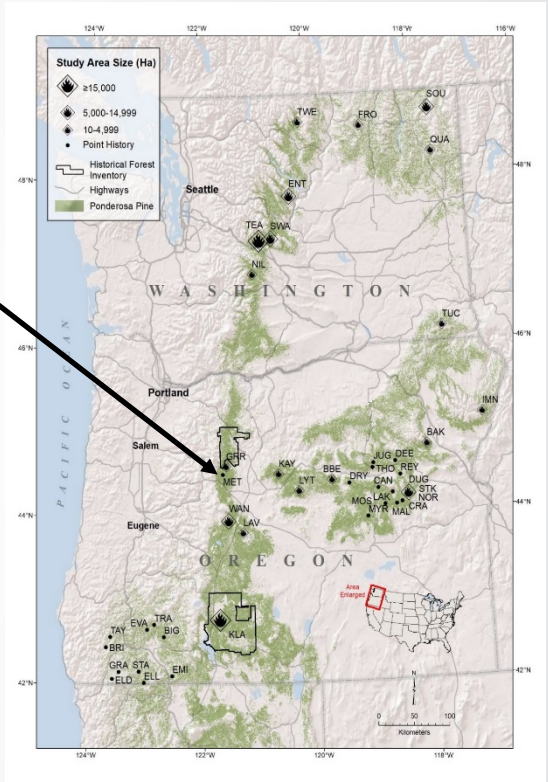


Duration of sustained droughts is 3-28 years, mean of 13 years
Return interval of 19-219 years, mean of 83 years (Keen et al, 1937).

Reconstruction of drought history in Oregon



Ponderosa pine range



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Mortality rates in Oregon and Washington

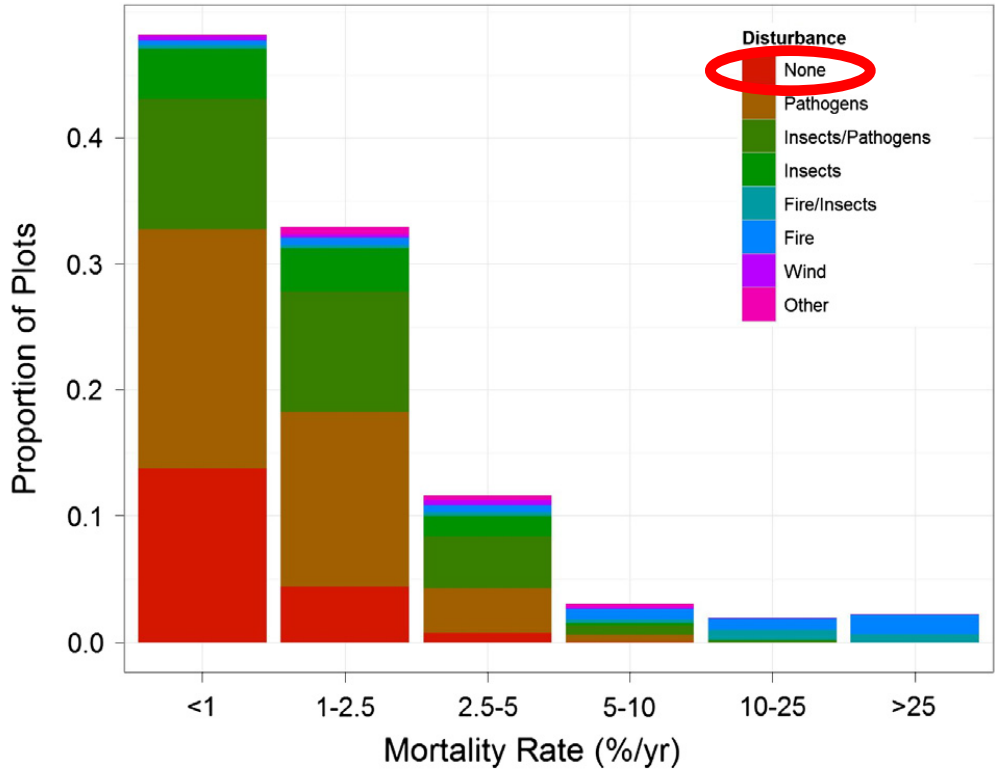
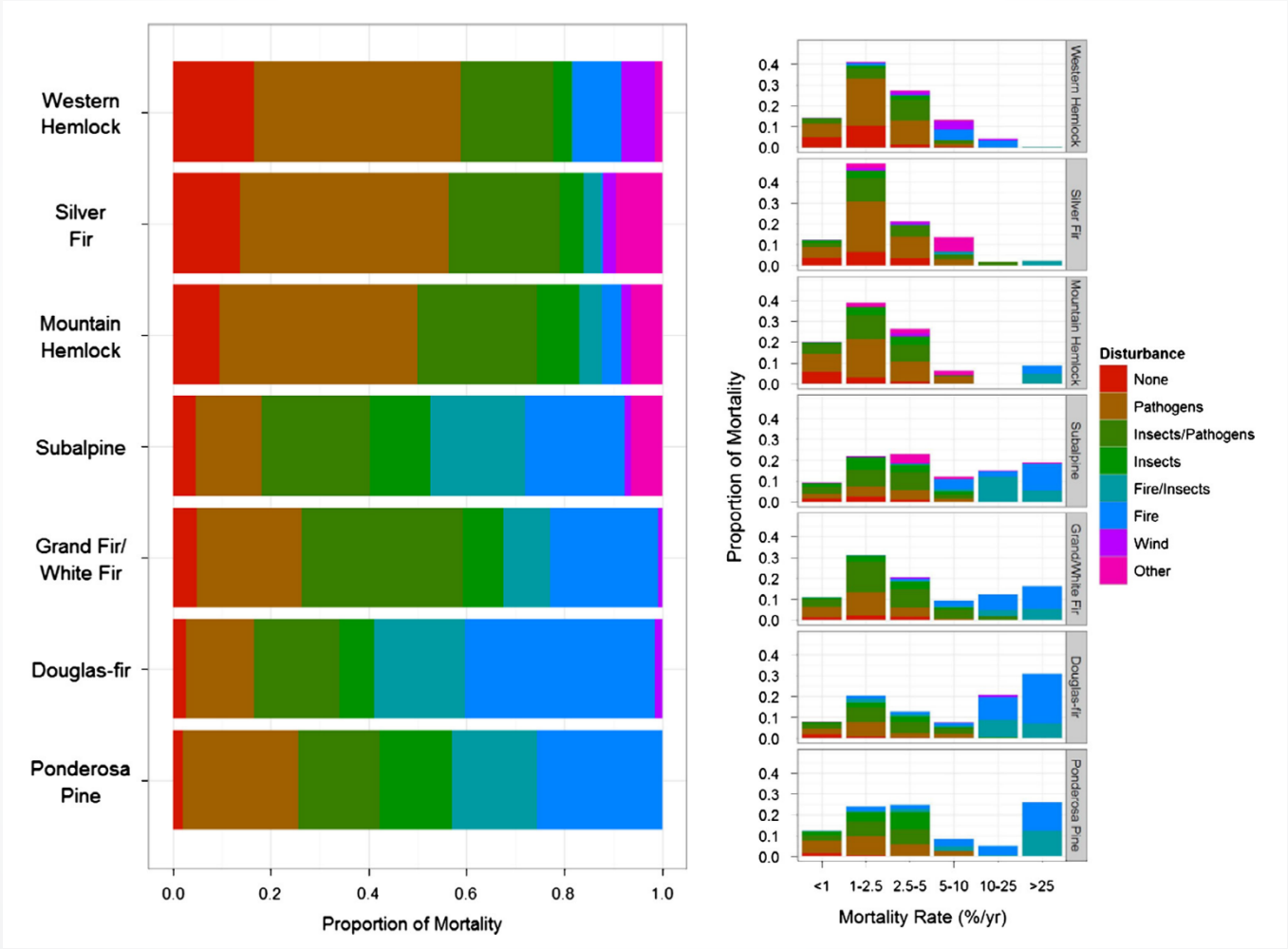


Fig. 3. Distribution of mortality rates by disturbance agent from the mid-1990s to the mid-2000s on USFS lands in Oregon and Washington.

Reilly and Spies (2016)

Mortality rates by species

Drought Tolerance

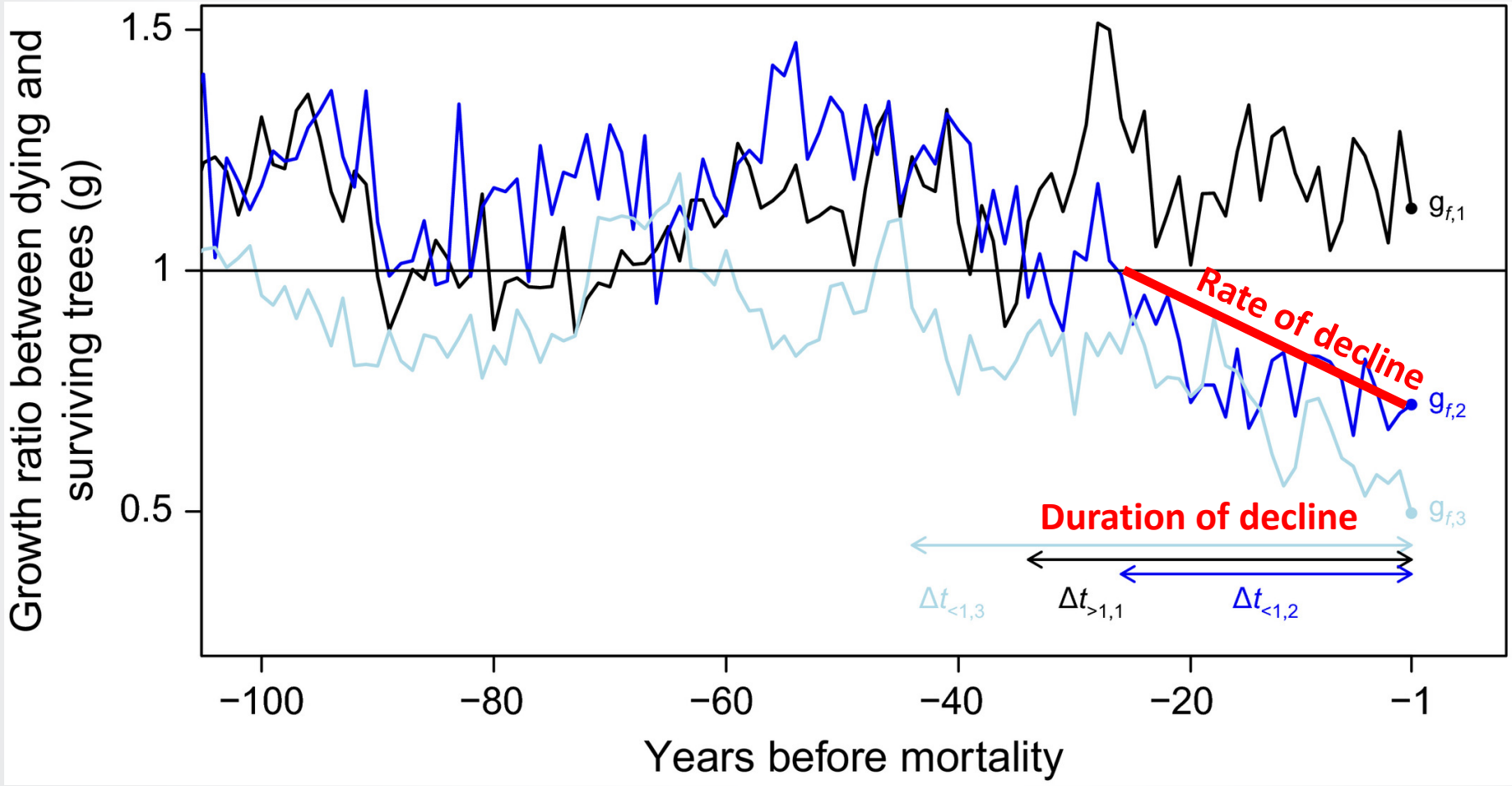


Reilly and Spies (2016)

Critical research needs to predict mortality (Axelson et al 2019)

- A landscape-scale understanding of what factors predispose forests to mortality.
- A set of key factors, or indicators, that identifies when a mortality event is occurring and where forests are most vulnerable.
- Projections of how tree species changes could affect ecosystem services.
- Tools to prevent and respond to tree mortality.

Tree growth decline as early warning indicator of mortality (Cailleret et al 2017)

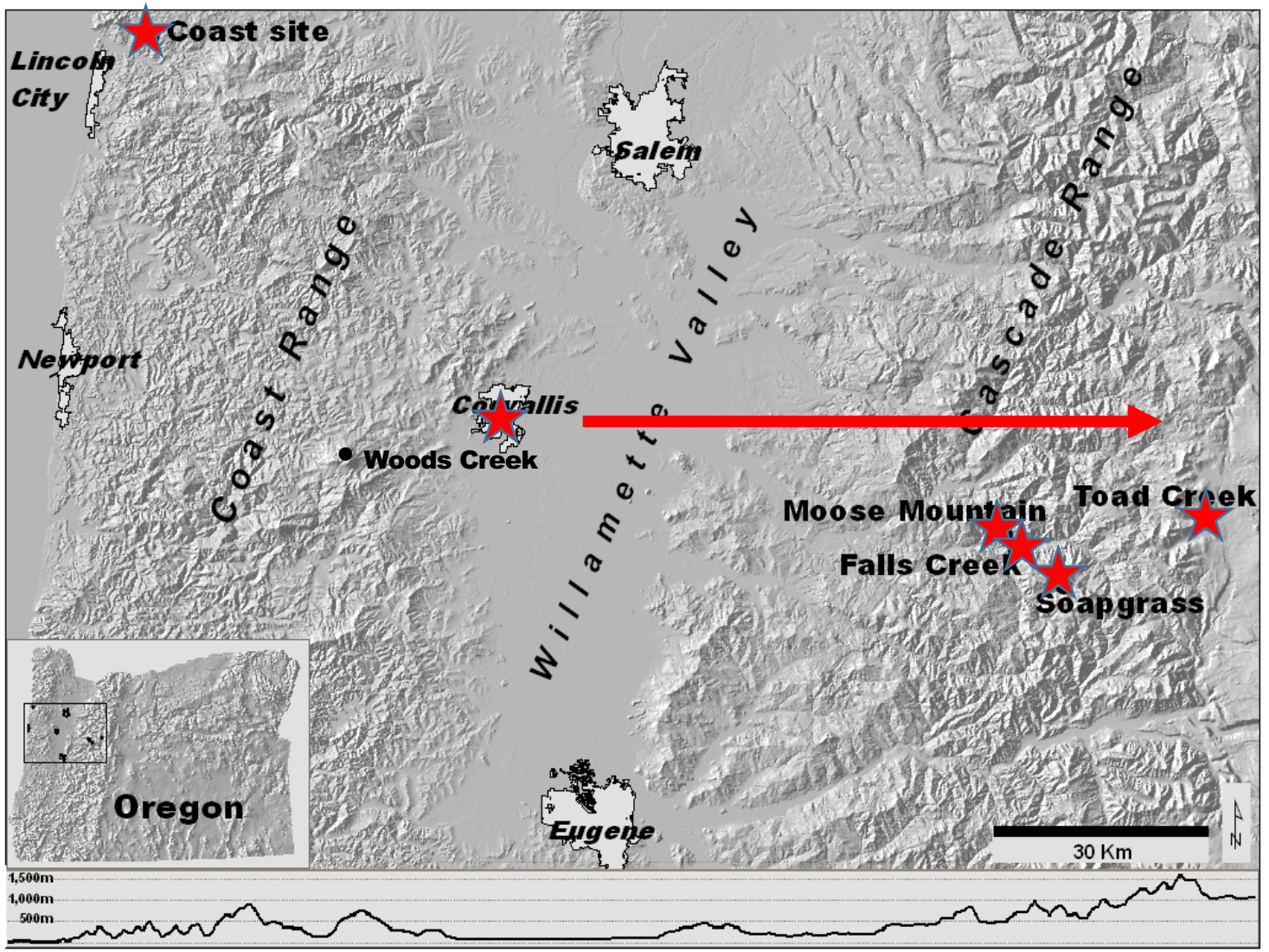


Risk of mortality increases with decreasing slope and increasing duration

Objectives

- Examine the growth trends of co-existing Douglas-fir and western hemlock along an elevational transect from the Willamette Valley to west slopes of the Cascade Range of Oregon.
- Examine spatiotemporal patterns in soil moisture and soil temperature 1996-present in western Oregon.
- Determine the key climatic factors influencing tree growth decline across western Oregon.
- Identify where forests are most vulnerable to decline and mortality in response to changing climate.

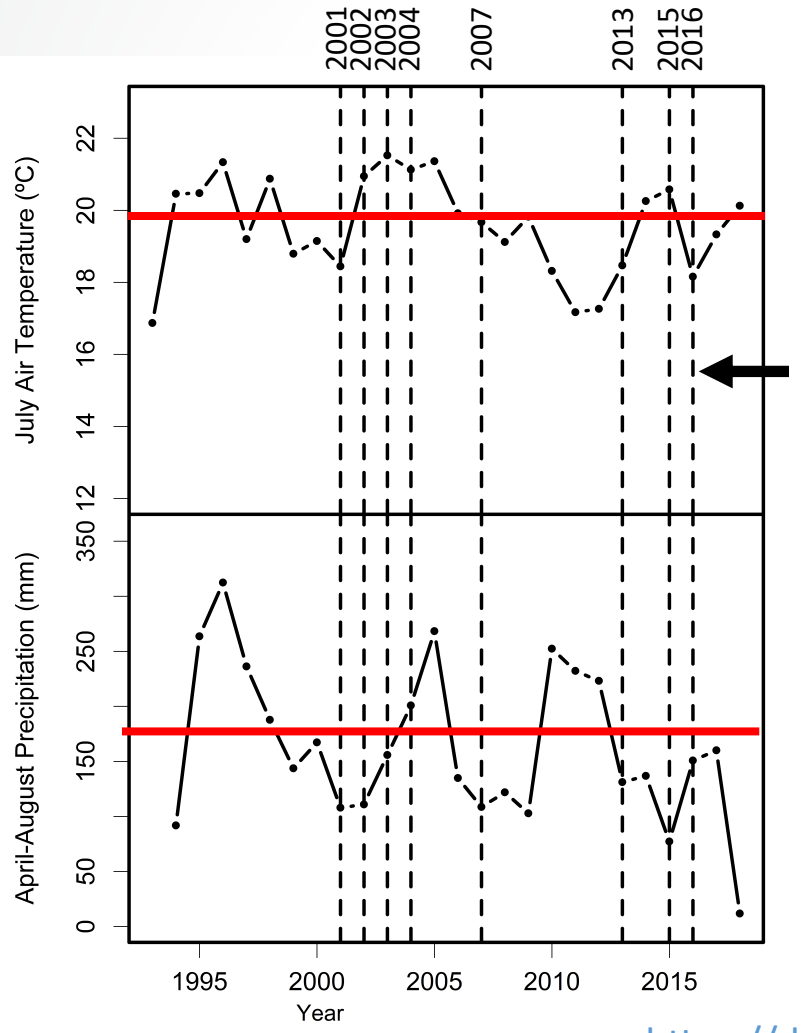
Tree core sampling sites and EPA met stations



Tree mortality rate due to drought is higher at low elevations (Willamette Valley) than higher elevations (Axelson et al 2019).

★ EPA Meteorological station

Tree Mortality in Willamette Valley (Forest Health Highlights in Oregon)

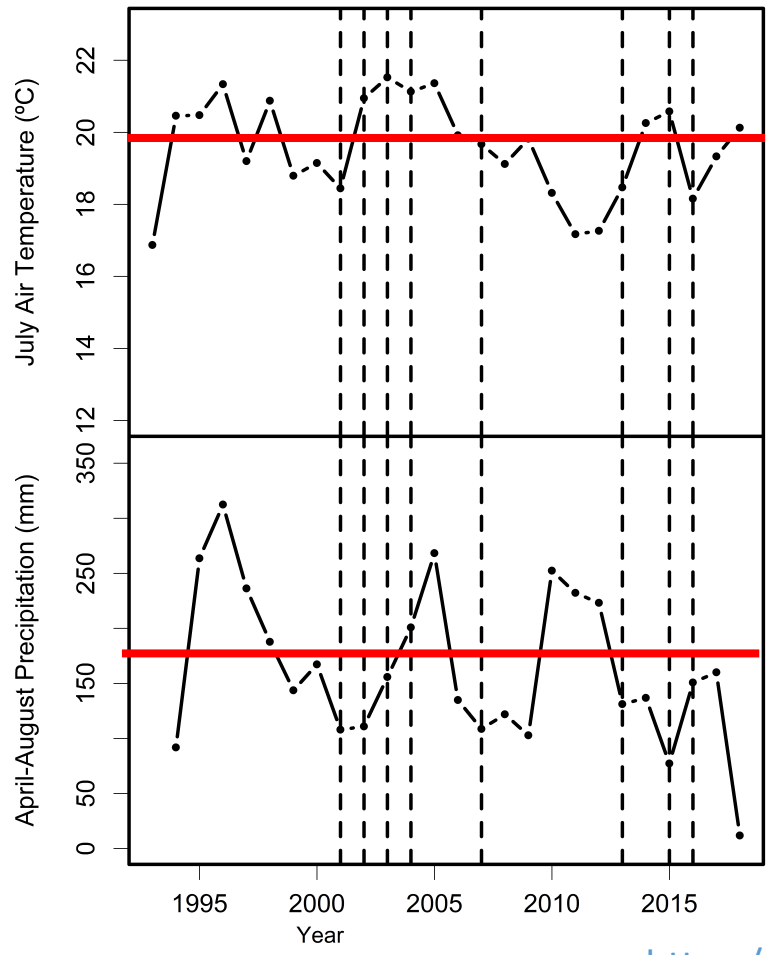


Observed mortality of Douglas-fir, true firs, w redcedar

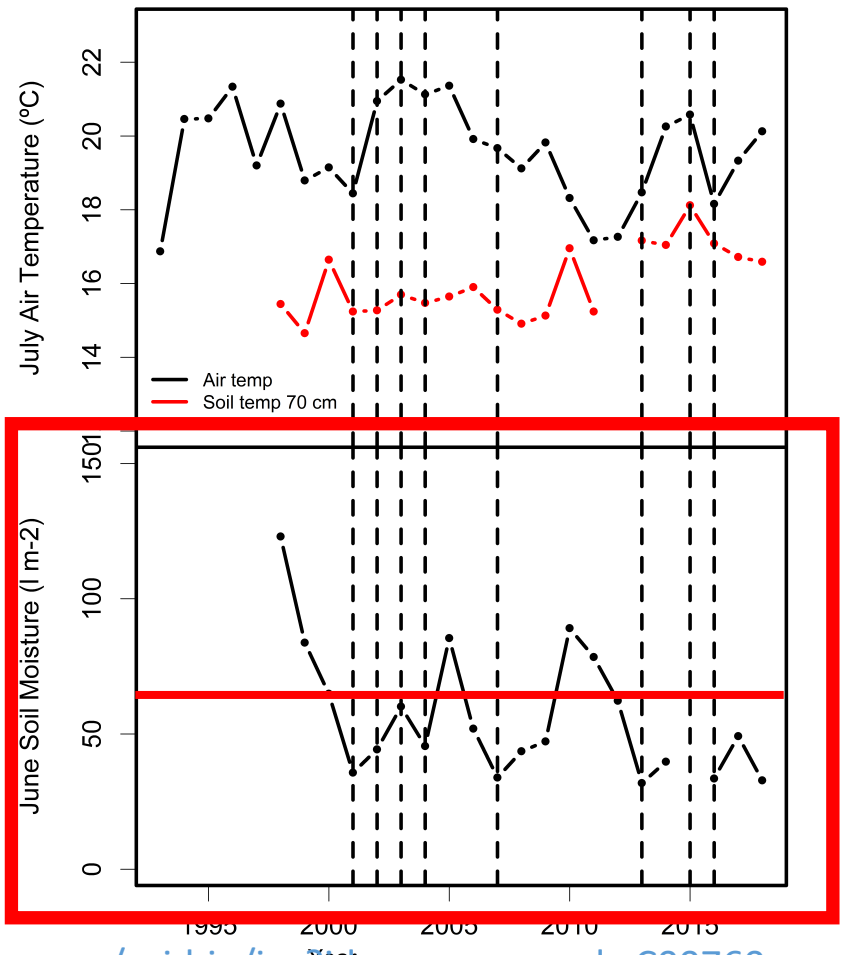
https://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.ncdc:C00760

Willamette Valley

Atmospheric variables

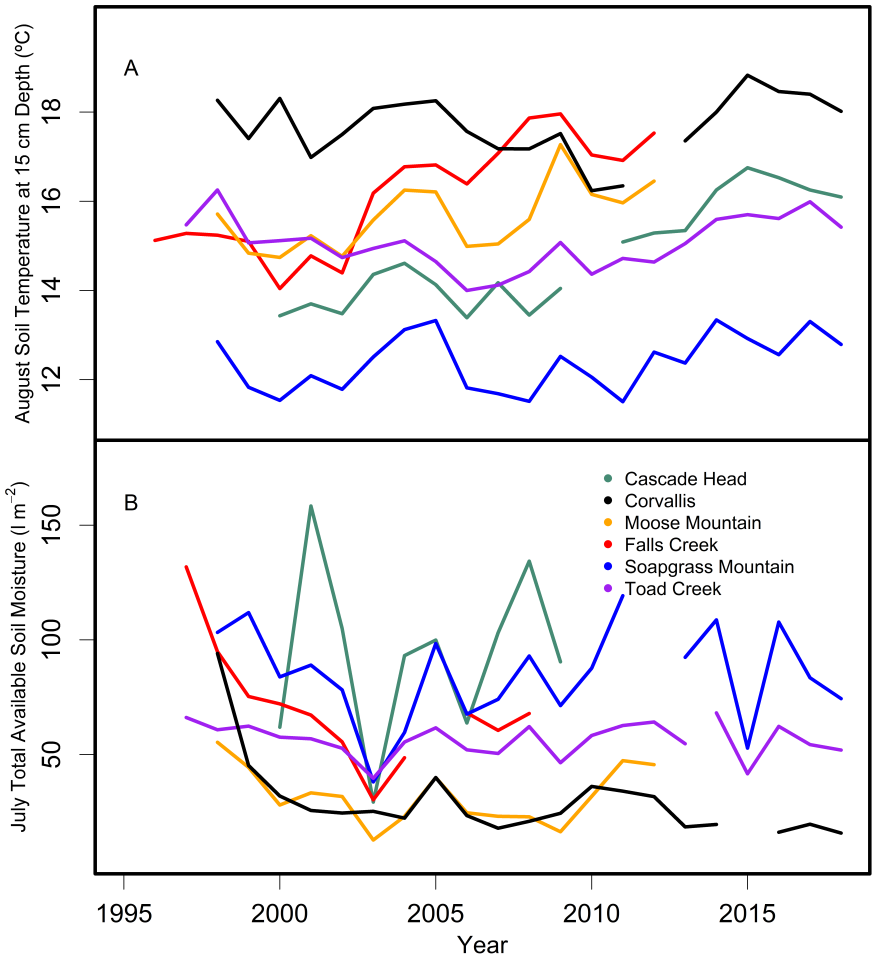


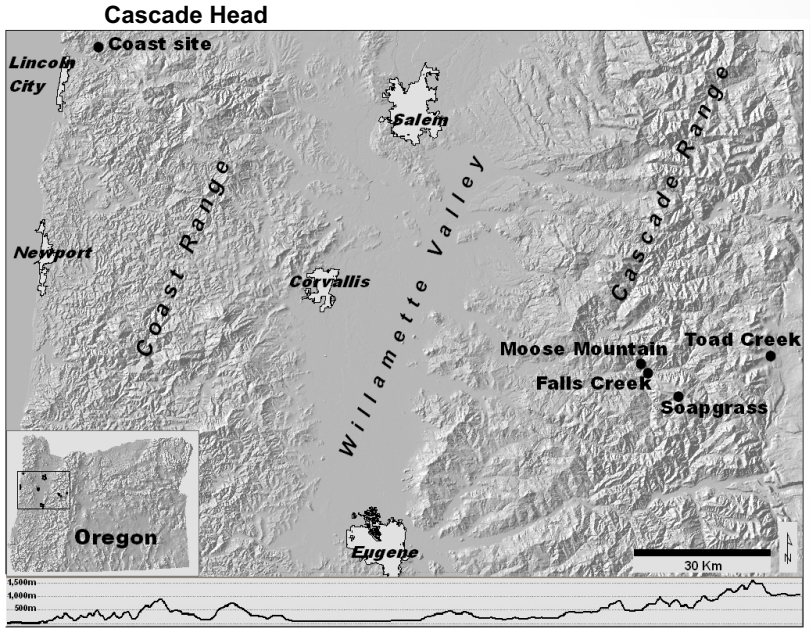
Edaphic variables



https://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.ncdc:C00760

Soil moisture and temperature 1996-2018





Soil temperature is increasing at a rate of >1ºC/decade versus 0.3ºC/decade for air temperature (Abatzoglou et al. 2014)

https://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.ncdc:C00760

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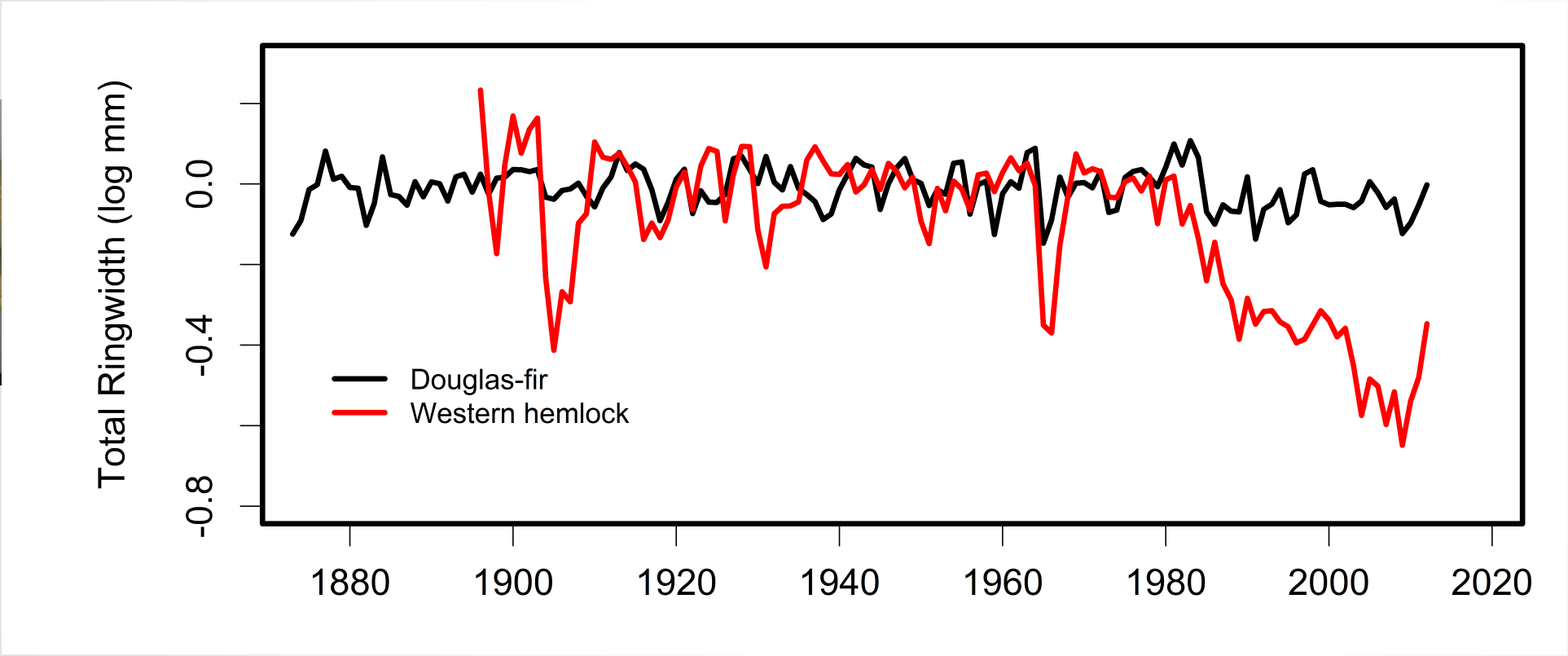
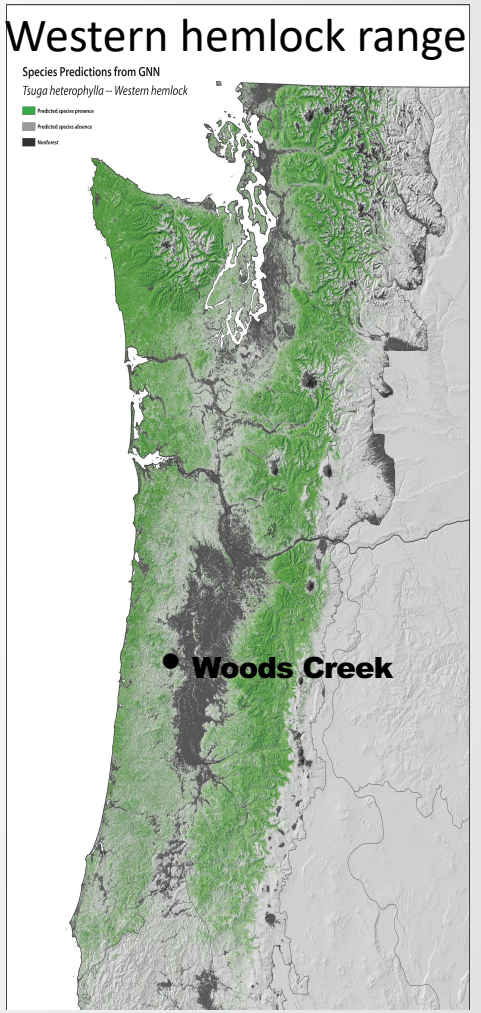
Woods Creek 525 m elevation

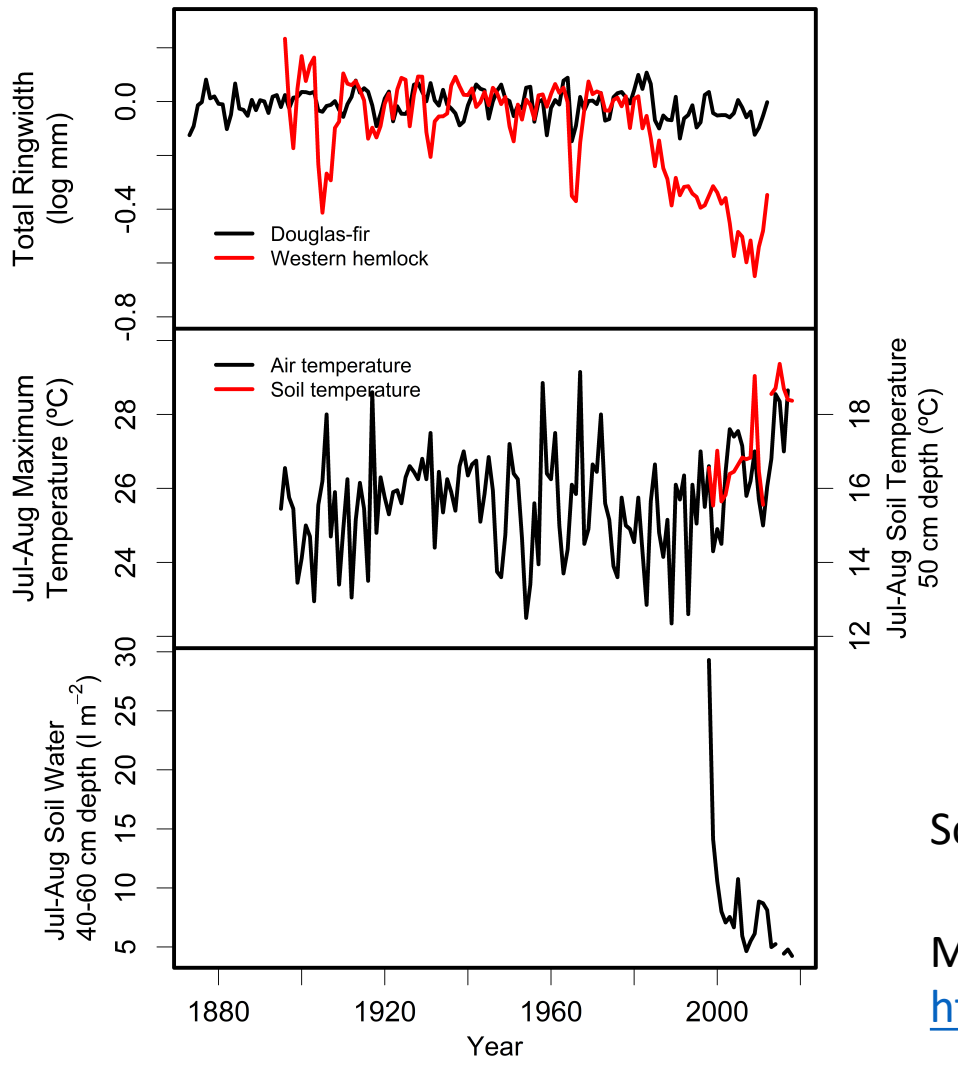
Basal area density = 72 m^2/ha

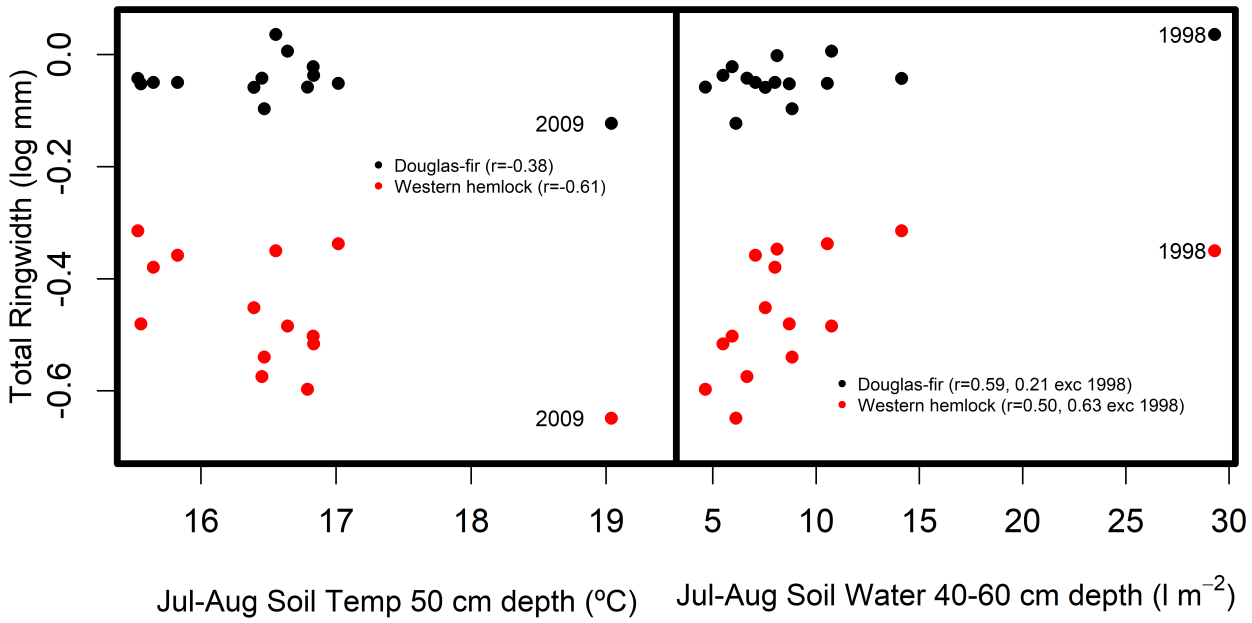
Douglas-fir (147 years old)/Western hemlock (136 years old)





Woods Creek (near Mary's Peak)





Soil temperature and moisture data from EPA met station in Corvallis

Monthly air temperature from PRISM climate group at OSU
http://www.prism.oregonstate.edu/

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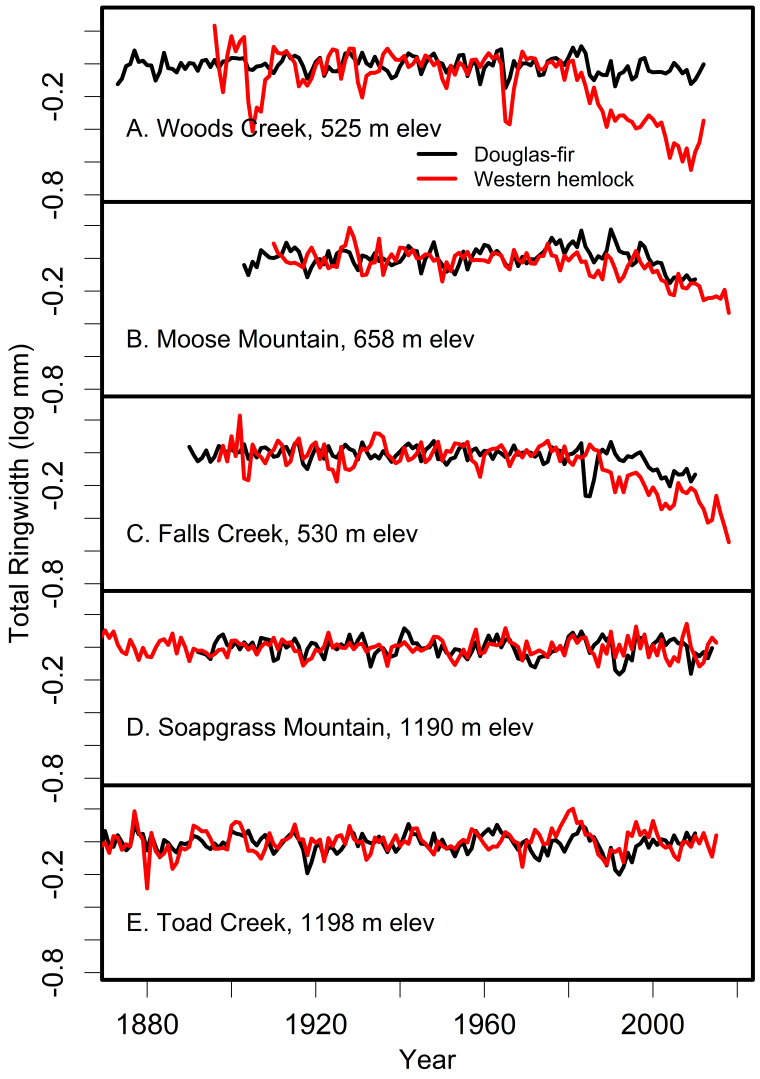
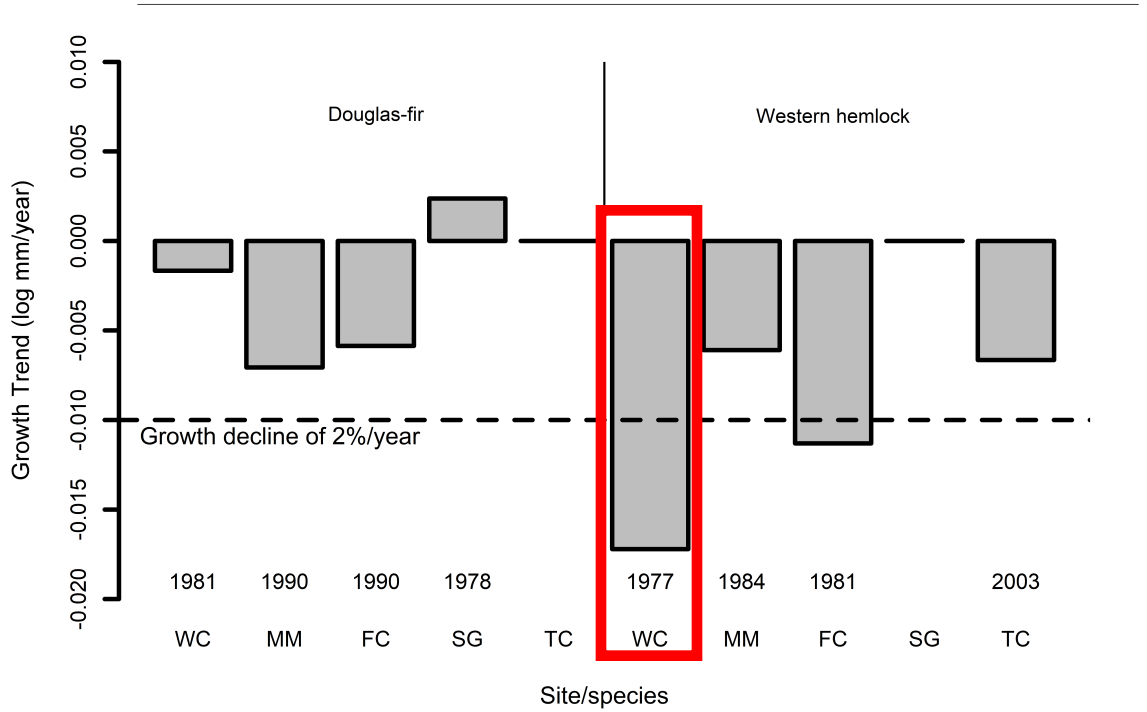
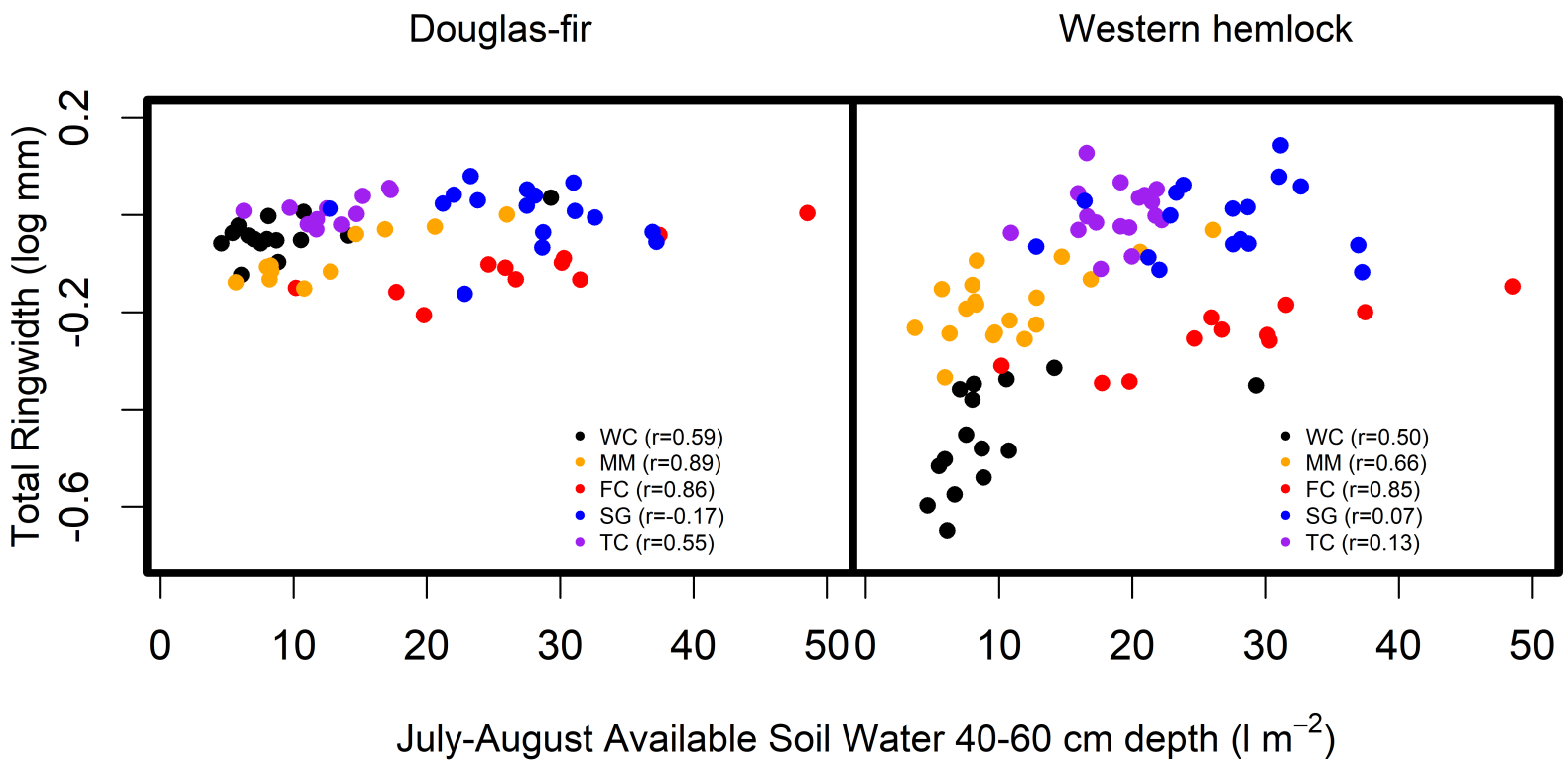
Growth decline in W Oregon



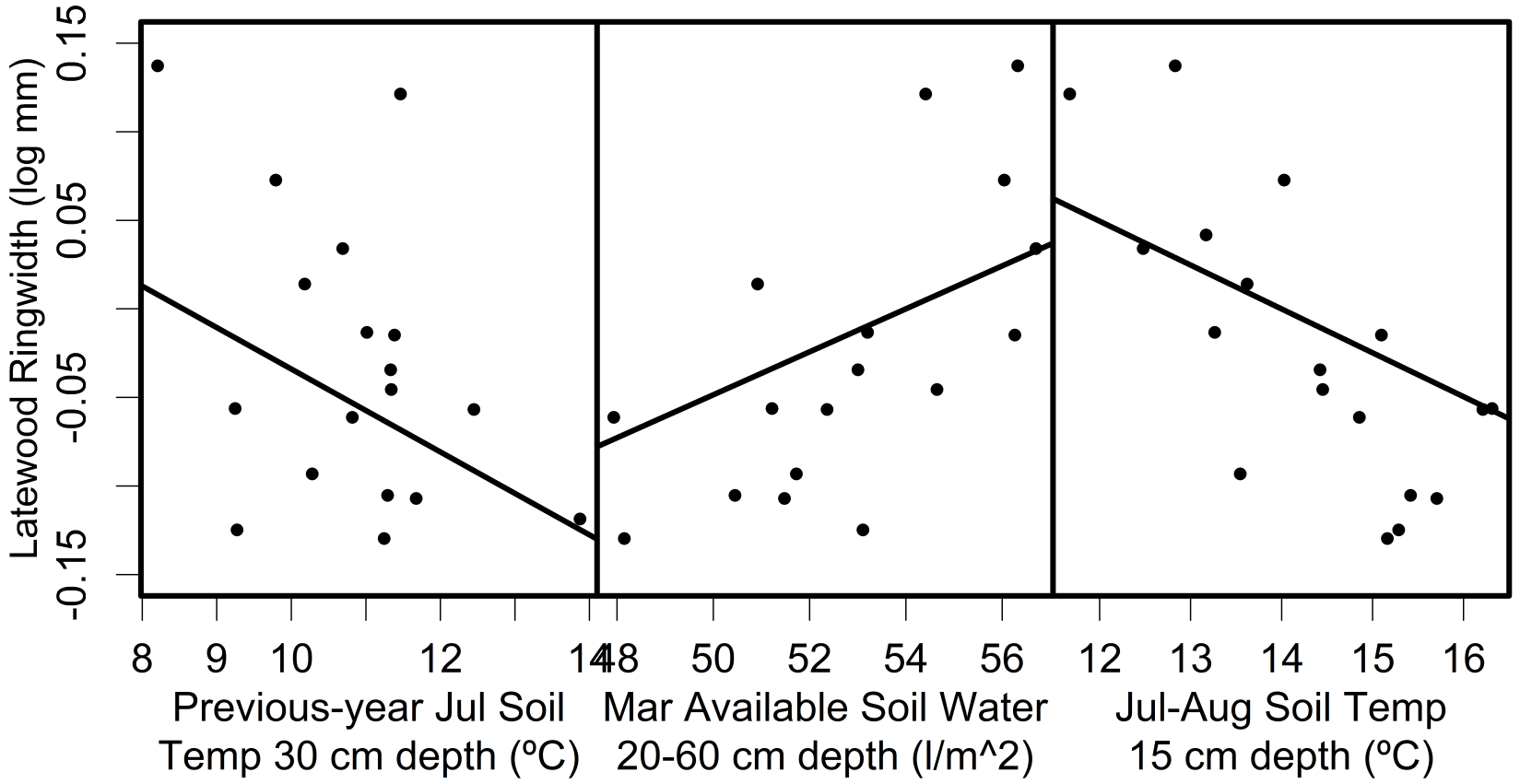


Drought-induced growth decline in W Oregon

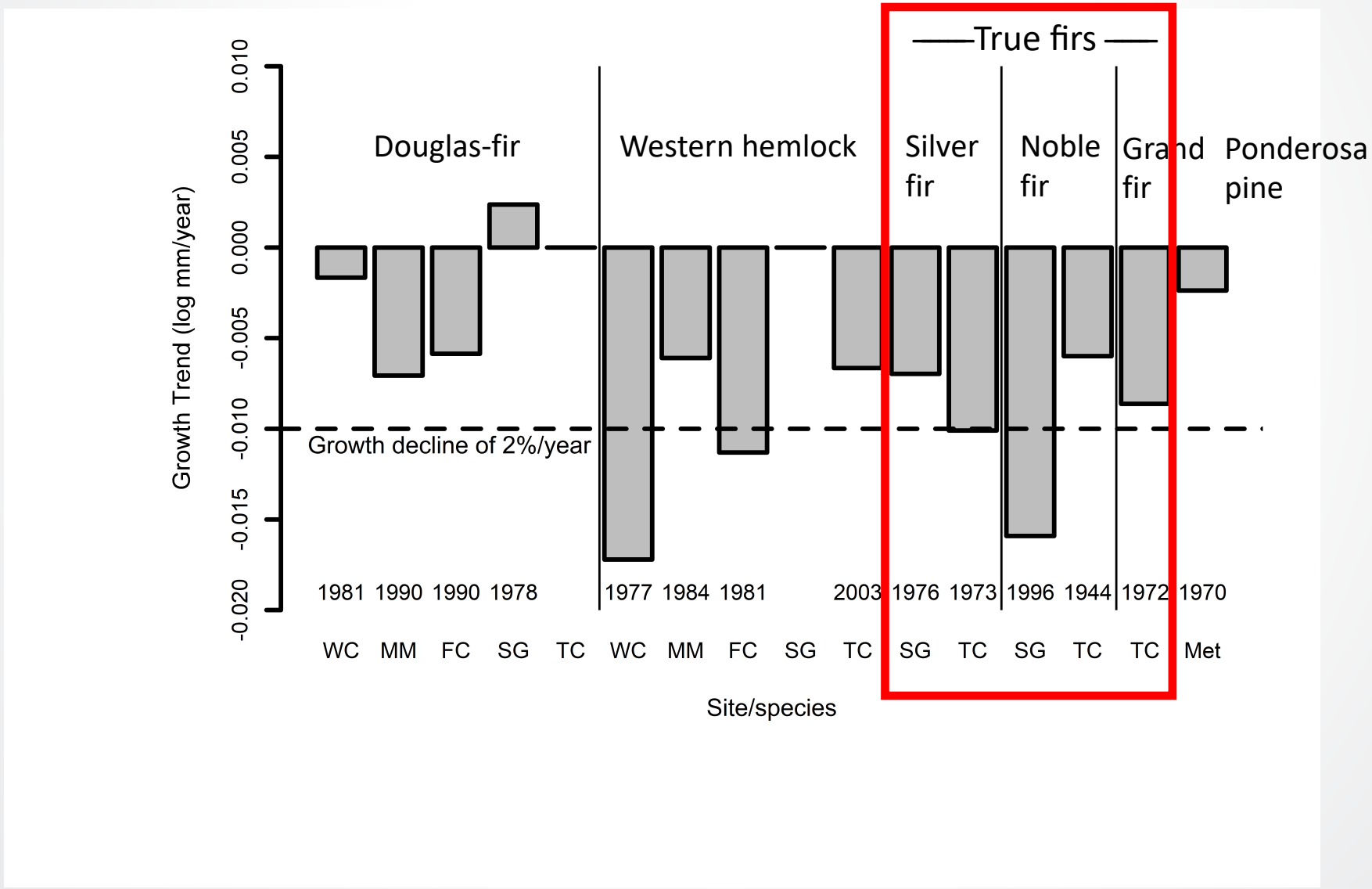


Toad Creek western hemlock

$Latewood_t = -0.063 – 0.023\ July\_Soil\_Temp_{t-1} + 0.012\ Mar\_Soil\_Water_t – 0.025\ Jul\text{-}Aug\_Soil\_Temp_t,\ R^2=0.96$



Growth decline by species and site



Conclusions

- Regional tree growth declines in western Oregon inland are an early warning indicator of future mortality.
- Tree growth decline and mortality at lower elevations are more highly associated with decreasing soil moisture and increasing soil temperature than air temperature and precipitation.
- Less drought-tolerant tree species, notably western hemlock and true firs, are most vulnerable to decline and mortality at low elevations in and adjacent to the Willamette Valley. True firs and w hemlock are also declining at higher elevations.
- Limited soil moisture has long been associated with constraints on forest productivity and when combined with extreme drought events can lead to widespread tree mortality (Anderegg et al. 2019).

Thank you!