Drought impacts on forest biomass mortality from fires and insects across the western United States during recent decades

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Photo: Rio Grande NF (USFS 2014)

Background

Forests in the western United States are strongly influenced by water availability and disturbance events. Rising temperatures and declining mountain snowpack are reducing water availability in many areas, coinciding with an increase in forest disturbance by fires and insects. We are examining the (1) carbon implications of forest disturbance by fires and insects across this region during recent decades and (2) the role of water availability in shaping patterns of disturbance and biomass distribution.

Science Questions

Focusing on forest disturbance by fires and insects across the western United States:

I. Which forested areas experienced the greatest biomass mortality during recent decades?
II. Have annual biomass mortality rates changed in recent decades?
III. Were annual biomass mortality rates associated with interannual variability in drought?
IV. How does long-term water availability affect biomass density and disturbance rates?

General Approach

We generated an ensemble-average forest biomass map[1-3] and then calculated annual forest biomass mortality (Mg C ha^{-1}) by combining the biomass map with estimates of annual percent tree mortality from fires [1984-2011; 4, 5] and insects [1996-2011; 6], following a previously developed approach [7]. We then derived correlations between annual biomass mortality and monthly lagged PRISM climate data [8]. Lastly, we examined forest disturbance rates (1996-2011) and aboveground biomass along the region-wide gradient in average annual water availability.


Photo: Castle Rock Fire (NIFC 2007)

Conclusions

I. Cumulative forest biomass mortality from insects was approximately twice that of fires between 1996 and 2011
II. Fires had the greatest impact in the Pacific Northwest, while insects had the greatest impact in the Interior West
III. Annual forest biomass mortality from fires and insects increased significantly during recent decades
IV. Biomass mortality from fire correlated with single-year drought, while increased mortality from insects was linked with multi-year drought
V. Forest biomass density increased with water availability and disturbance rates peaked in dry areas with moderate forest biomass density

Results

Spatial patterns of forest disturbance

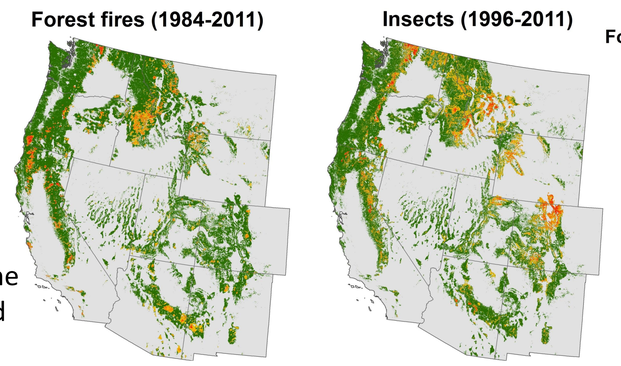

Fig 1. Cumulative forest biomass mortality from fires (1984-2011) and insects (1996-2011) across the western United States

Temporal patterns of forest disturbance

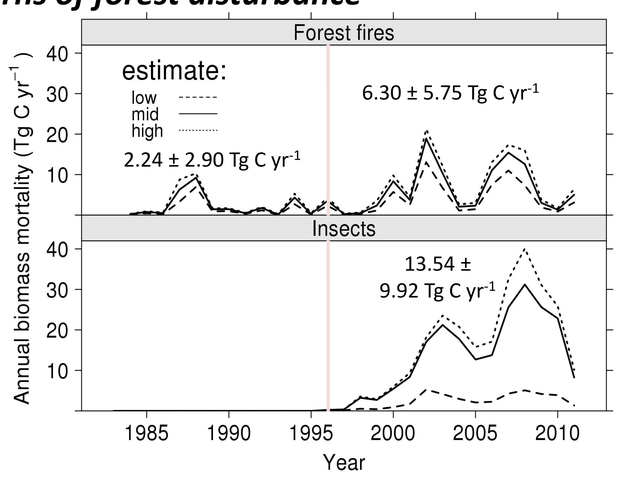

Fig 2. Estimates of annual forest biomass mortality from fires and insects across the western United States. Each line represents an estimate based on different assumptions.

Forest biomass, disturbance and water availability

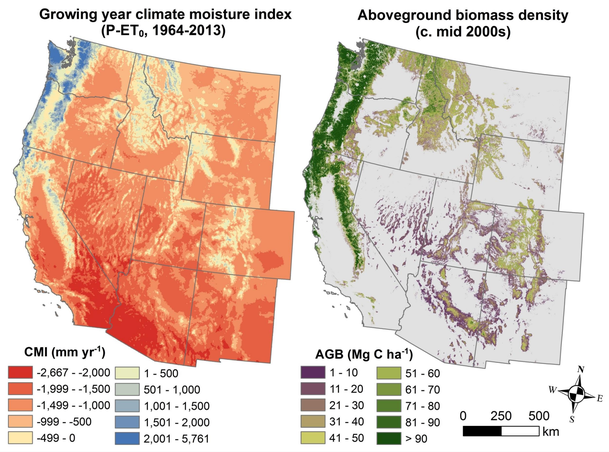

Fig 4. Steep gradients in mean annual water availability (left) and forest biomass (right) occur and coincide across the western United States.

I. Total forest biomass mortality from insects and fires was 216 [39,257] and 100 [66,120] Tg C, respectively, between 1996-2011
II. Biomass mortality from fires was highest in CA (27%), ID (17%), and OR (15%), while mortality from insects was highest in CO (19%), MT (17%), and WA (17%; Fig. 1)
III. Annual biomass mortality from fires (1984-2011) and insects (1996-2011) increased significantly ($P<0.05$) over the respective periods of observation (Fig. 2)
IV. Drought impacts differ by region and by disturbance type (Fig. 3)
V. Long-term water availability exerts a strong influence on average forest biomass density ($r^2=0.97$), as well as on annual disturbance rates by insects and fires (Fig. 4,5)

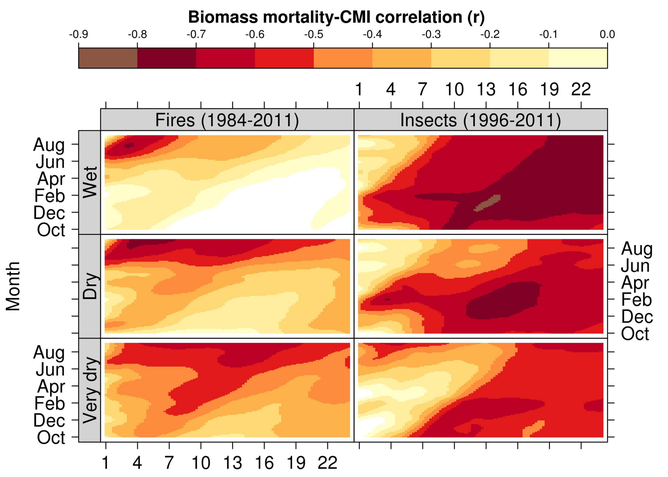

Fig 3. Correlations between annual biomass mortality and monthly lagged climate moisture index (CMI = P-ET_0) for the western United States divided into three moisture regimes.

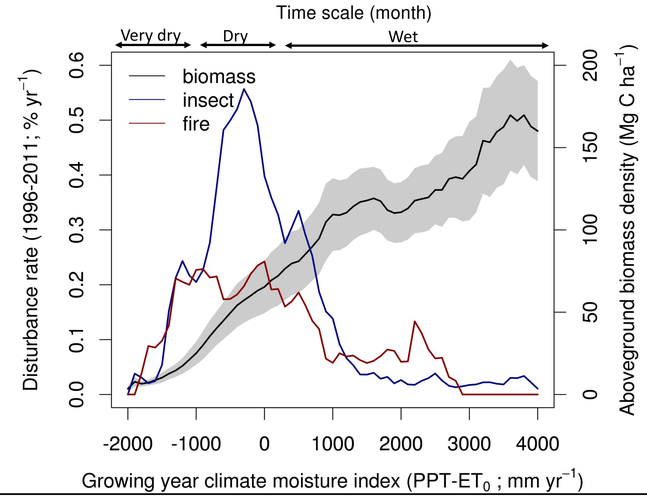

Fig 5. Average annual disturbance rates and forest biomass density summarized across the western United States based on 50-yr average annual water availability.

References

1. Blackard, J., et al., Rem. Sens. Env., 2008; **2.** Wilson, B.T., et al., Carbon Bal. Man., 2013; **3.** Kellndorfer, J., et al., 2012: ORNL DAAC; **4.** Eidenshink, J., et al., Fire Ecol., 2007; **5.** Ghimire, B., et al., J. Geophys. Res. Biogeosci. 2012; **6.** Meddens, A.J., et al. Ecol. App., 2012; **7.** Hicke, J.A., et al., Env. Res. Let., 2013; **8.** Daly, C., et al., Int. J. Clim., 2008.

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