The Impact of Water Stress on Net Carbon Exchange at the Wind River Old-growth Forest, Washington, USA

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One traditional ecological paradigm predicts that after a serious disturbance, forest systems start as a strong carbon source to the atmosphere, shift into a strong sink after a few years, peaking after some decades, and then decline as a sink until reaching carbon equilibrium. Conversely, some studies have demonstrated that older ecosystems under favorable climate conditions continue to be significant carbon sinks. The regional implications of this variation derived from limited surface data (e.g., eddy covariance flux sites) is critical for identifying and quantifying the role of terrestrial ecosystems in climate change and the converse, the effect climate change on terrestrial ecosystems.

Here we present six years of eddy-covariance carbon and water fluxes at the Wind River Canopy Crane Research Facility (WRCCRF), a 500 year old coniferous forest in southern Washington, USA (45.821, -121.952, 365 m asl). Long-term flux data show exceptionally high interannual variability in atmosphere-ecosystem carbon exchange, implying that this old-growth forest ecosystem may not be in “steady state” conditions. In this paper we focus on the relationship between water availability and carbon sequestration at WRCCRF with the objective of quantifying the impact of water stress on net carbon exchange. While this forest has high biomass and a complex canopy, it experiences water stress during the regular, summer drought.

Our results show that mean dry-season water use efficiency (WUE) varied from 1.8 mg g^{-1} in 1999 to 3.9 mg g^{-1} in 2003. WUE in 1999 was significantly lower than any other year ($P < 0.0001$) coinciding with very wet, La Niña conditions. We found evidence that summertime soil respiration is attenuated ~ 40 to 50% during the summer drought compared to respiration in late spring/early summer. When modeling ecosystem respiration, a respiration attenuation factor based on soil moisture and understory net ecosystem exchange (NEE) data had to be derived for the years with the greatest water stress in order to not overestimate respiration for this ecosystem.

Links between carbon exchange and precipitation suggest that water availability is an important factor in determining whether or not the old-growth forest becomes an annual carbon sink, source, or is at equilibrium. However restrictions on water availability can limit respiration during the driest years and therefore moderate the impact of drought on the annual carbon balance. Implications of this work may be significant considering that the region is predicted to have more extreme and prolonged drought periods.