Water And Carbon Fluxes Along An Elevation/Precipitation Gradient In A Sagebrush Steppe Environment

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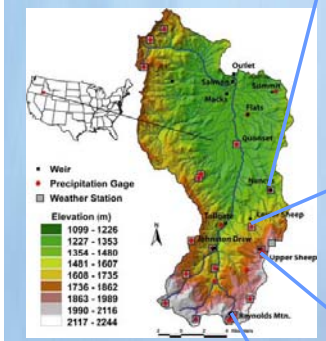
Summary

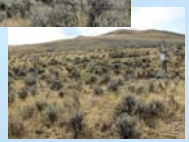
Environmental gradients exert controls on water, carbon and energy fluxes across montane landscapes, impacting the magnitude and timing of evapotranspiration, carbon uptake, water stress, and water use efficiency. Four eddy covariance systems were situated along an elevation gradient in Idaho's Owyhee Mountains. The sites are part of the Reynolds Creek Critical Zone Observatory and contribute to an ongoing long-term environmental monitoring network in the USDA's Reynold's Creek Experimental Watershed. The sites include a Wyoming big sagebrush site, a low sagebrush site, a post-fire mountain big sagebrush site, and a mountain big sagebrush site located at elevations of 1425, 1680, 1808 and 2111 m. Variations in climate follow the montane elevation gradient; mean annual precipitation at the sites is 290, 337, 425, and 795 mm, respectively, and mean annual temperature is 8.9, 8.4, 6.1, 5.4°C. Evapotranspiration (ET) peaked about a month earlier at the lower elevation sites, but with limited precipitation the vegetation also encountered water stress much earlier. The ratio of ET to potential evapotranspiration (PET) indicated that plants experienced less water stress for a large part of the growing season at higher sites. Water use efficiency tended to be lower at the Wyoming big sagebrush site, presumably due to the more bare ground and water loss to soil evaporation. Simulation results to assess effects of climate change suggest that gross ecosystem productivity (GEP) at the lower elevation sites are water-limited while that at the higher elevations may be limited by the length of the growing season.



Site Descriptions

Wyoming Big Sagebrush

Located at our Nancys study site, the Wyoming big sagebrush site is lowest in elevation of the four sites. Precipitation is dominated by rainfall and the site was bare of snow for much of the winter.



Elevation: 1425 m
Avg Precip: 295 mm
Mean temp: 8.9°C

Low Sagebrush

The low sagebrush site is located at our Lower Sheep Creek study site. Low sagebrush dominates the site but grass and forb production in the spring can be appreciable. Like the Nancys site, it was bare of snow for much of the 2015 water year.

Elevation: 1680 m
Avg Precip: 337 mm
Mean temp: 8.4°C

Post-fire Sagebrush

A prescribed fire conducted in 2007 consumed the Mtn big sagebrush at the Upper Sheep Creek site. Recovering vegetation is largely snowberry, grasses and forbs, with some sagebrush now returning. Winter snow accumulation at the site is typically 1 m, but was less than 25 cm for much of the 2015 winter.

Elevation: 1808 m
Avg Precip: 505 mm
Mean temp: 6.1°C

Mountain Big Sagebrush

The Mtn big sagebrush site located near our Reynolds Mtn. study site is the highest of the four sites. Precipitation is dominated by winter snow accumulation.

Elevation: 2111 m
Avg Precip: 802 mm
Mean temp: 5.4°C

Eddy Covariance

Eddy covariance systems were run at the four sites. Standard EC corrections were applied. Missing evapotranspiration (ET) fluxes were gap-filled by regression with potential ET for the surrounding 14-day period. We filled net ecosystem exchange (NEE) and partitioned the net carbon flux into ecosystem respiration and gross ecosystem production (GEP) using the REddyProc software developed at the Max Planck Institute for Biogeochemistry

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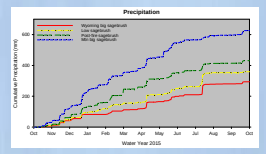
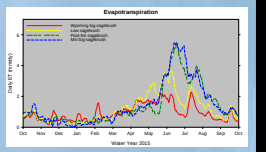
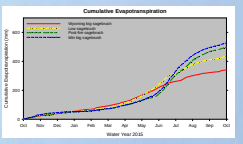
Results



Reynolds Creek has cool, wet winters and hot, dry summers. 2015 snowmelt was complete on March 15 at the Post-fire and Mtn big sagebrush sites; the two lower elevation sites were bare of snow nearly all winter. April and July rainfall offset the relatively dry winter.

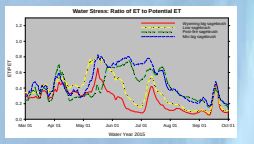
Limited precipitation and soil moisture storage resulted in a sharp decrease in ET during June at the two lower elevation sites, however July rains caused a dramatic increase in ET.

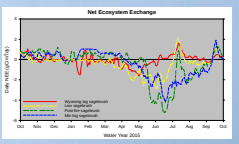




Comparison of cumulative ET between the sites is consistent with differences in measured precipitation.

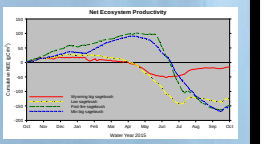
Water stress at the different sites, taken as the ratio of ET to potential ET (ET/PET), is consistent with available precipitation and ET plotted for the sites. The two higher elevation sites transpired at nearly PET for much of the summer period and did not experience appreciable water stress until August.

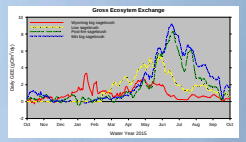




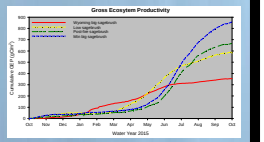
The graph of daily NEE indicates carbon uptake (negative NEE) at all sites early in the spring, but each site transitioned to a carbon source beginning with the low elevation Wyoming big sagebrush site. Seasonal NEE responds very similarly at the two higher elevation sites, with carbon uptake not occurring until May, but persisting into September.

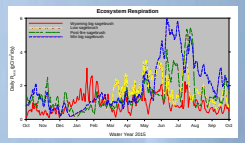
Annual NEP for the sites indicated that the low elevation Wyoming big sagebrush site was nearly carbon-neutral for 2015, while the other sites with higher precipitation input stored approximately 150 gC/m^2.





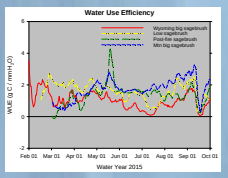
Although ecosystem productivity began early (Jan/Feb) at the low elevation Wyoming big sagebrush site, the higher elevation sites quickly outpaced its productivity upon arrival of spring after snowmelt.

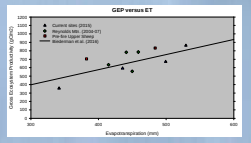




July rains at the three lower elevation sites caused a dramatic rise in respiration. Grasses and forbs had already senesced at the two lower elevation sites and could not take advantage of the water; thus there is no concomitant increase in GEP.

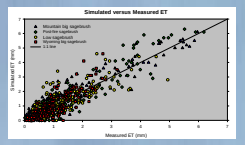
Water use efficiency tended to be lower at the Wyoming big sagebrush site, likely due to more bare ground and soil evaporation. July rains caused a decrease in WUE at the two lower elevation sites likely due to wet surface soil and increased soil evaporation.



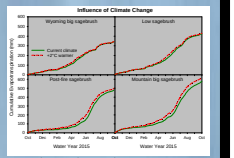


The relationship between annual GEP and ET is consistent with previous measurements made at RCEW as well as the regression between GEP and ET presented by Biederman et al. (2016) for 21 sites from the semiarid southwestern U.S.

Biederman, J.A., et al. 2016. Terrestrial carbon balance in a drier world: the effects ofwater availability in southwestern North America. *Global Change Biology*, 22, 1867–1879, doi: 10.1111/gcb.13222



Evapotranspiration was simulated with the Simultaneous Heat and Water (SHAW) Model. The model was then used to assess the impact of a +2°C climate change.



ET at the two lower elevation sites was nearly unchanged under a warmer climate scenario, but the mountain big sagebrush site increased by 42 mm. This suggests that GEP at the lower elevation sites are water-limited while that at the higher elevation is limited by the length of the growing season.