# Comparison of Energy and Carbon Fluxes of Sagebrush and Aspen Canopies within a Small Mountainous Catchment


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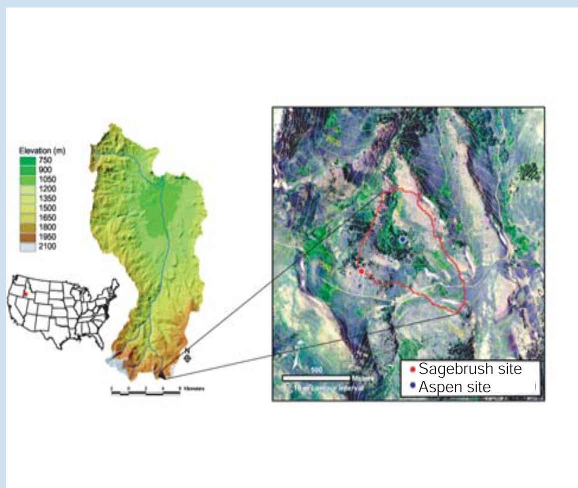
## Objectives

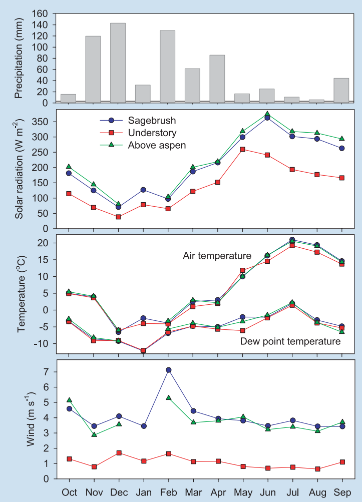
The focus of this study was to compare and contrast surface energy and carbon fluxes across a headwater catchment characterized by large variability in precipitation and vegetation cover to elucidate the roles that the different vegetation types have in modifying the timing and magnitude of the energy and carbon fluxes. Energy and carbon fluxes were compared for a sagebrush site, an aspen understory, and above the aspen canopy during 2007.

Three eddy covariance sites were established to monitor fluxes across the RME catchment as part of a long-term study to characterize the hydrology of this mountainous headwater catchment.




## Study Area

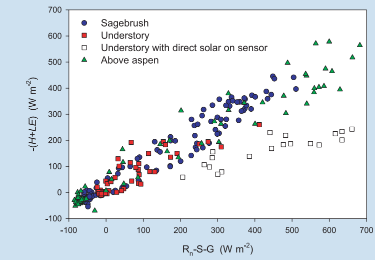
The study area is the Reynolds Mountain East (RME) catchment located in the southwestern portion of the Reynolds Creek Experimental Watershed (RCEW) operated by the USDA Agricultural Research Service, Northwest Watershed Research Center. RME ranges in elevation from 2028 to 2137 m.




## Meteorological Conditions

Total precipitation measured during the 2007 water year (October 2006 through September 2007) was 690 mm at the sagebrush site and 718 mm at the aspen site.

Meteorological conditions are very similar for the sagebrush and above aspen, while the solar radiation and wind speed are moderated considerably for the aspen understory. Solar radiation measured below the aspen reaches a maximum in May prior to the aspen trees leafing out. Typical wind speeds below the aspen are 1 m/s while those above the aspen and sagebrush are around 4 m/s.



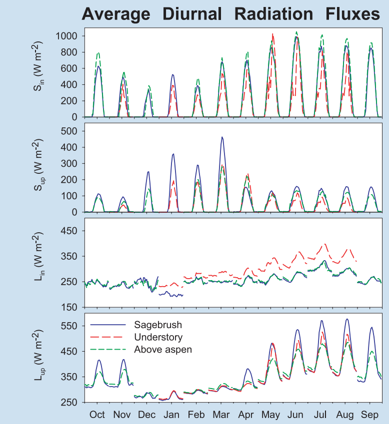

| Site | Slope | Intercept | $R^2$ |
|---|---|---|---|
| Sagebrush | 0.84 | 22.5 | 0.96 |
| Aspen understory | 0.38 | 19.2 | 0.76 |
| Aspen understory (excluding mid-afternoon hours) | 0.70 | 12.6 | 0.80 |
| Above aspen | 0.74 | 29.5 | 0.95 |

## Energy Balance Closure **

Slope of the turbulent fluxes (H+LE) versus radiation (Rn), canopy storage (S) and ground heat flux (G) were quite reasonable for the sagebrush and above aspen sites. Gaps in the canopy exposed the net radiometer in the understory to direct radiation during the mid-afternoon hours (as shown in the graph of radiation fluxes to the right) resulting in poor energy balance closure for the understory. Excluding these hours from the energy balance closure analysis improved the slope of the regression line.

***** All fluxes are postive downward***

## Average Diurnal Radiation Fluxes




## Radiation Fluxes

The problems presented by the gaps in the canopy for measurement of the understory net radiation is apparent in the plot of incoming total radiation ($S_{in}$).

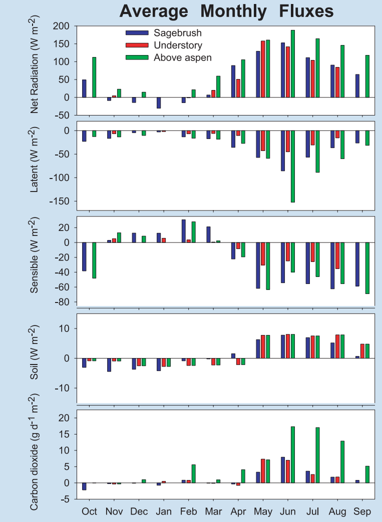
Although incoming solar radiation is lower during the winter months, reflected radiation ($S_{out}$) is actually higher due to the high albedo of the snow.

Sheltering provided by the aspen canopy is evident from the much higher downward long-wave radiation ($L_{in}$) for the aspen understory.

Upward long-wave radiation ($L_{out}$) is nearly identical for the sagebrush and aspen understory early in the year until the snowcover becomes discontinuous at the sagebrush site in late March.

Evaporative cooling of the aspen trees substantially lowers the surface temperature and upward long-wave radiation flux from the aspen compared to the other sites.

## Average Monthly Fluxes




## Seasonal Fluxes **

Growing season (May through September) net radiation, latent heat and carbon flux are consistently higher for the aspen site.

Evapotranspiration at the sagebrush is higher in October and April compared to the other sites due to early snowmelt and the perennial leaves on the sagebrush.

Net Radiation and latent heat flux peaks in May in the aspen understory prior to the aspen trees leafing out.

Carbon flux to the sagebrush and aspen understory is very similar from June through August even though evapotranspiration is higher from the sagebrush canopy. Being more sheltered, the understory vegetation can use the available water more efficiently than the sagebrush at the more exposed site.

***** All fluxes are postive downward***

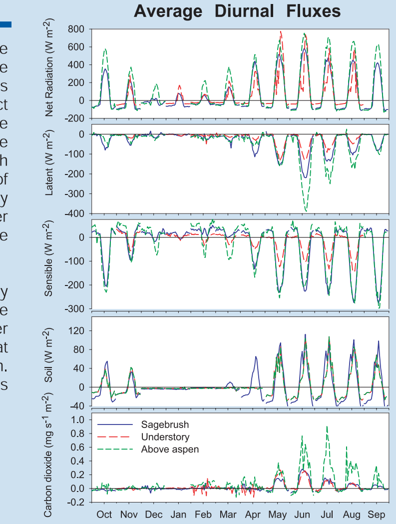
## Diurnal Fluxes **

The diurnal trend in sensible heat flux above the aspen and sagebrush sites are quite similar during the non-snow period (April through November). This might be expected, given that the two sites are subject to nearly identical meteorological forces. Average daily sensible heat fluxes (in the plot to the left) were more negative above the aspen than the sagebrush during October, May, and September. Absorption of solar radiation during these months was not offset by transpiration of the aspen, resulting in a higher proportion of the energy being dissipated by sensible heat flux.

Soil heat flux is essentially constant and slightly negative through the winter. It then becomes positive and displays a diurnal trend when snowcover becomes discontinuous, which occurs in late March at the sagebrush site and late April beneath the aspen. The sagebrush site, being more exposed, displays larger amplitude in the diurnal trace in soil heat flux.

***** All fluxes are postive downward***

## Average Diurnal Fluxes




## Sagebrush Site

Vegetation at the sagebrush site consists of about half sagebrush with the remainder consisting of equal amounts of native grasses and forbs. Maximum leaf area index (LAI) was 0.77

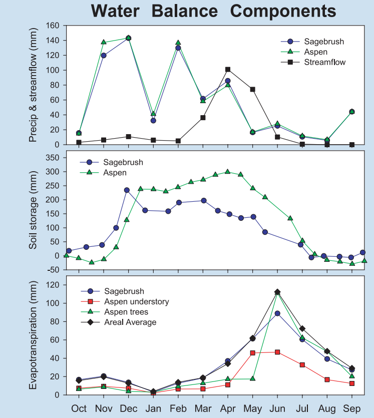
## Aspen Understory

Understory of the aspen consists of grasses and forbs with a maximum LAI of approximately 1.2.

## Above Aspen Canopy

Average height of the aspen was 9.5 m and the effective canopy height was 15 m. Stem area index of the trunks and limbs prior to the growing season was 0.5. Maximum LAI of the aspen measured during the growing season was 1.35 in August.

## Water Balance Components




## Water Balance for the 2007 Water Year

| | | | | |
|---|---|---|---|---|
| Precipitation | | | | 700 mm |
| Evapotranspiration | Site ET | % of area | Areal Contribution | |
| Sagebrush | 399 mm | 66% | 263 mm | |
| Understory | 205 mm | 34% | 70 mm | |
| Aspen trees | 318 mm | 34% | 108 mm | |
| Total | | | | -441 mm |
| Streamflow | | | | -254 mm |
| Soil Water Change | | | | - 1 mm |
| Error | | | | -6 mm |

About 36% of the precipitation exits the catchment in streamflow. Evapotranspiration accounts for 63% of the precipitation.

Due to its larger coverage within the catchment, sagebrush accounts for approximately 60% of the total evapotranspiration, while the aspen understory accounts for 15% and the trees account for 25%.

## Conclusions

This study highlights the influence of vegetation and site conditions on surface energy and carbon fluxes across small landscapes. Differences in the surface energy and carbon fluxes between the three sites were modulated by the characteristics of the three vegetation types.

Perennial leaves of the sagebrush enabled higher rates of evapotranspiration and latent heat flux during the early and late portions of the growing season compared to the aspen site. Conversely, the aspen understory experienced the highest net radiation, carbon, evapotranspiration, and latent heat fluxes in May, prior to the aspen trees leafing out. Latent heat and carbon flux at the aspen site during this period originated almost entirely from the understory.

The presence of the aspen also modulated the partitioning of the turbulent fluxes at the site; sensible heat flux from the aspen tended to be slightly less than the sagebrush site during the growing season when the leaves were actively transpiring, but exceeded that from the sagebrush in May, September and October when net radiation was not offset by evaporative cooling of the aspen leaves.

Carbon flux to the sagebrush and aspen understory was very similar for much of the growing season, even though evapotranspiration was higher from the sagebrush canopy. Being more sheltered, the understory vegetation used the available water more efficiently than the sagebrush at the more exposed site. Carbon flux to the aspen trees far surpassed that used by either the aspen understory or sagebrush.