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Landscape and plant physiological controls on water dynamics and forest productivity within a watershed

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Across the Western U.S., declining snowpacks have resulted in increased water limitation, leading to reduced productivity in high elevation forests. While our current understanding of how forests respond to climate change is typically focused on measuring/modeling the physiological responses and climate feedbacks, our study aims to combine physiology with hydrology to examine how landscape topography modulates the sensitivity of forests to climate. In a forested watershed in Western Montana, we linked climate variability to the physical watershed characteristics and the physiological response of vegetation to examine forest transpiration and productivity rates. Across the entire watershed, we found a strong relationship between productivity and the topographic wetness index, a proxy for soil moisture storage. However, this relationship was highly dependent on the intensity of solar radiation, suggesting that at high elevations productivity was limited by temperature, while at low elevations productivity was limited by moisture. In order to identify the mechanisms responsible for this relationship, we then examined how different coniferous species respond to changing environmental and hydrologic regimes. We first examined transpiration and productivity rates at the hillslope scale at four plots, ranging in elevation and aspect across the watershed. We found trees growing in the hollows had higher transpiration and productivity rates than trees growing in the side slope, but that these differences were more pronounced at lower elevations. We then used oxygen isotope to examine water source use by different species across the watershed. We found that trees growing in the hollows used snowmelt for a longer period. This was most likely due to upslope subsidies of snowmelt water to the hollow areas. However, we found that trees growing at lower elevations used proportionally more snowmelt than trees at the higher elevations. This was most likely due to the trees at lower elevation depending on deeper, more reliable water when the upper soils dried down during midsummer. These observations suggest that landscape topography influences the availability of soil water, which influences tree transpiration and productivity rates, thereby leading to watershed patterns of productivity.