Vegetation water use and stream flow at the H.J. Andrews

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BACKGROUND, GOALS: This project became part of the LTER4 program in 1999 as a sub-component of the "small watersheds" synthesis area. Our overall goal has been to better understand how vegetation age, structure, and species composition affect hydrological patterns in the H.J. Andrews. Obviously, this is far too ambitious for the available funding, so we set specific objectives for each year. In 1999, our primary objective was to evaluate differences in water use by hardwoods and softwoods in WS1. In 2000, we used streamflow and sapflow data for both WS1 and WS2 to examine the temporal dynamics relating these two processes. Also, the focus of sapflow questions shifted to a comparison of young vs. older conifers in WS1 and WS2. This focus continued in 2001. In addition, Georgianne Moore established a project in 2001, as part of her dissertation, to determine how species mixtures affect water use.

OBJECTIVES AND HYPOTHESES:

I. Analysis of species influences on vegetation water use in the riparian area of WS1. The specific objectives of this study were 1) to measure and compare summer water use of a dominant angiosperm (red alder, *Alnus rubra*) and gymnosperm (Douglas-fir, P*seudotsuga menziesii*) in WS 1, and 2) to estimate summer water use by all woody vegetation in the riparian zone, which we defined as a 100m strip centered on the stream. This defined a 12.7 ha study area. We tested the following hypotheses: 1) Maximum water use by red alder (per unit sapwood area) is greater than Douglas-fir, 2) Diurnal variation in sapflow is greater for Douglas-fir than for red alder (due to greater sensitivity to VPD), and 3) Water use by red alder relative to Douglas-fir should increase through the growing season as atmospheric humidity decreases.

II. Comparing the dynamics of streamflow and sapflow in WS1. The objective of this work is to analyze statistical relationships between sapflow and streamflow records on both diel and seasonal time scales. Specifically, we have been looking for correlations between changes in flux rates and, by using lag analysis, the temporal relationships between sapflow and streamflow.

III. Comparing vegetation water use in WS1 and WS2. The objective of this work is to test the hypothesis that transpiration rates per unit sapwood area are significantly lower in old (200+ years) Douglas-fir compared with young-mature trees (20-50 years) (as predicted by the "hydraulic limitation" hypothesis). Also, we seek to determine whether there are differences between the two watersheds in summer water use by vegetation in the "riparian" areas (defined arbitrarily as 50 m to either side of the stream), and whether these differences can help us understand long-term trends in streamflow (related to part II).

RESULTS:

1. Species influences on vegetation water use in WS1.

As expected, hardwoods used significantly more water than hardwoods on a unit sapwood area basis. Average daily sapflow was 1074 kg m^{-2} sapwood day^{-1} and 759 kg m^{-2} sapwood day^{-1} for red alder and Douglas-fir, respectively. There was no pronounced difference in the diurnal flux patterns between the two species. Average daily sapflow decreased for both species between July and September, but the decrease was much more pronounced for the conifers. To scale water use from our measured trees to the entire riparian area, we established a set of measurement plots in transects normal to the stream bed. In each plot we tallied the species, height, DBH and sapwood depth for every tree over 1 cm DBH, and from these data we estimated the distribution of vegetation and sapwood basal area throughout the study area. The estimated total sapwood basal area was 6.8 and 14.0 m^2 ha^{-1} for broadleaf and coniferous species, respectively. Assuming that the water use of red alder and Douglas-fir were representative of these functional groups, we estimated that the broadleaf vegetation averaged 0.73 mm day^{-1} water use and the conifers averaged 1.06 mm day^{-1}, for a total of 1.80 mm day^{-1} through the measurement period. Conifers used approximately 65% of the total transpired water in early July; this dropped to about 55% in late August (Fig. 1).

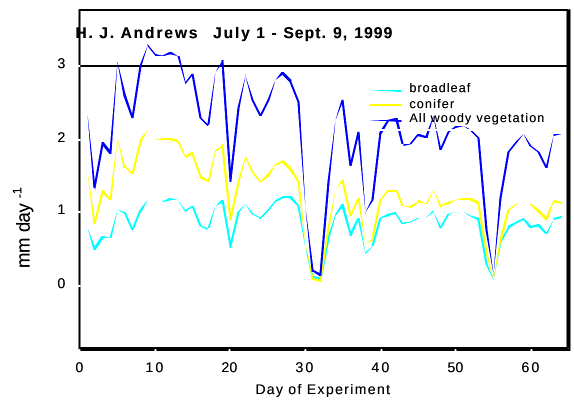


Fig. 1. Seasonal water use by conifers and broadleaf trees in the riparian zone of WS1 in 1999.

2. Temporal relationships between sap flow and stream flow

DIEL RELATIONSHIPS IN WS1. Both sapflow and streamflow showed a pronounced 24-hour periodicity (i.e., a "diel" pattern) in WS1 (Fig. 2). The time lag between maximum sapflow and minimum streamflow varied through the summer of 2000, with a minimum lag of about 3 hours in June, increasing to more than 10 hours by late August (Fig. 3). We estimated the "effective zone of vegetation influence" on short-term fluctuations in stream flow by dividing the daily amplitude in the streamflow record (m^3 H_2O of "missing" streamflow between daily peaks) by the daily total sapflow on a ground area

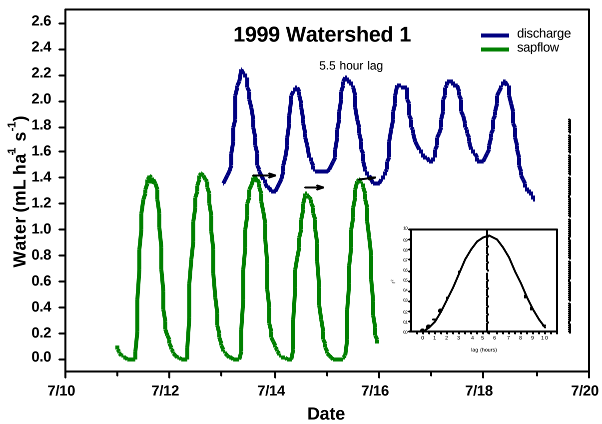


Fig. 2. Daily dynamics of sap flow and stream flow in WS1 in 1999

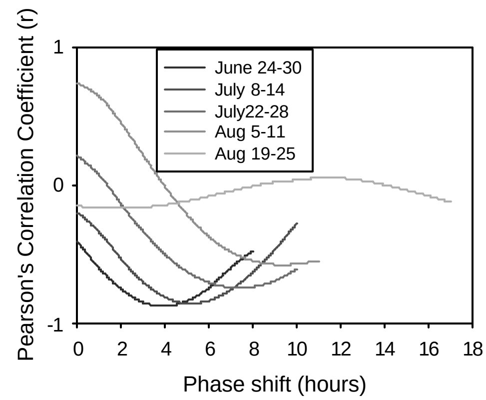


Fig. 3. Time lags between maximum sap flow and minimum stream flow in WS1 in 2000.

basis (m^3 H_2O transpired per m^2 ground area). The quotient is the effective ground area of transpiring vegetation that can account for the fluctuation in streamflow. This area turned out to be quite small, and it changed through the summer. The maximum "effective area" reached a maximum of 0.3 ha (or about 0.3% of the total watershed) in late June, declining to less than 0.1 ha by late summer.

SEASONAL RELATIONSHIPS IN WS1 and WS2.

Long term stream flow records indicate that average summer slow flows are currently slightly less in WS1 than in WS2 (Fig. 4) shows the differences for 2000). We compared the streamflow with sapflow based on measurements within the "riparian zone"

Fig. 4. Daily stream flows from June 1 - Oct. 15 1996 - 1998 means

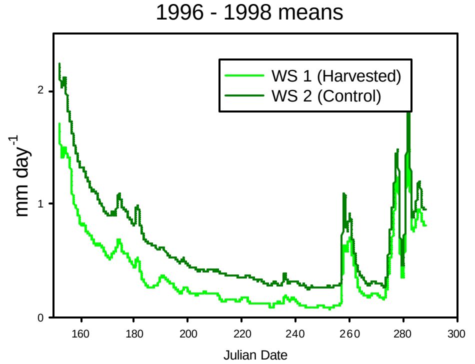
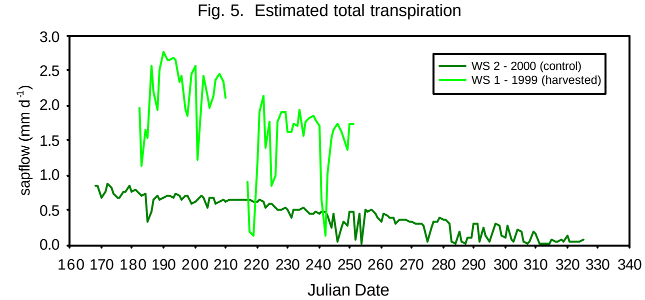
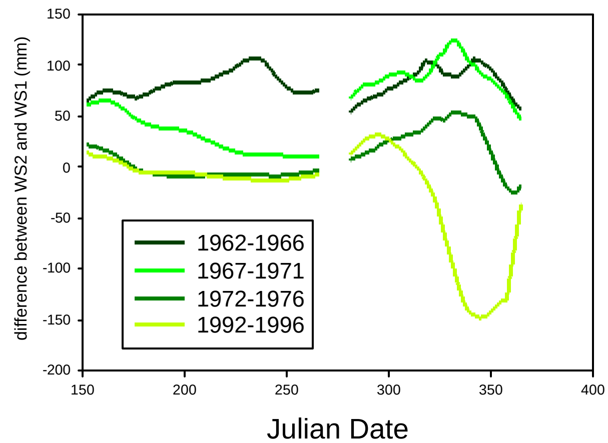


Fig. 5. Estimated total transpiration



(arbitrarily defined as a region 50 m to each side of the stream), and we found that our estimated differences in sapflow between the watersheds (Fig. 5) were far greater than the differences in streamflow. Thus, the sapflow data suggest a significant "water deficit" in WS1 that is not observed in summer streamflow. Julia Jones' analysis of long term streamflow records shows that in recent years, streamflow in WS1 has been significantly lower than WS2 over a short period of time in late November or early December (Fig. 6). This leads to the hypothesis, which we plan to explore further in the future, that the vegetation in WS1 extracts far more soil water than in WS2, resulting in a soil water deficit that is "filled" when fall rains resume – thus resulting in a short-term reduction in flows in WS1.

Fig. 6. Difference in base flow between WS1 and WS2 (5-year means)



3. Sapflow in young vs. old Douglas-fir, in old hemlock vs. old Douglas-fir

Transpirational water use in mid-summer was about 25% greater in large, old western hemlock compared with co-occurring old Douglas-fir (per unit sapwood), and the differences became even more pronounced in the fall.

Comparing age classes of Douglas-fir, sap flow per unit sapwood area in the old-growth trees in WS 2 was less than half of sap flow in younger trees in WS1 (Fig. 7).

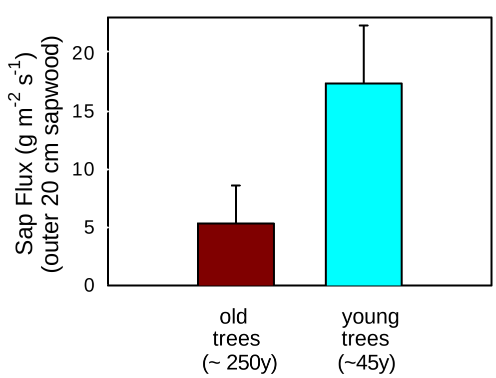


Fig. 7. Average sap flow per unit sapflow area for old vs. young Douglas fir averaged over the measurement period in 2000.

3. Vegetation water use in riparian areas of WS1 and WS2

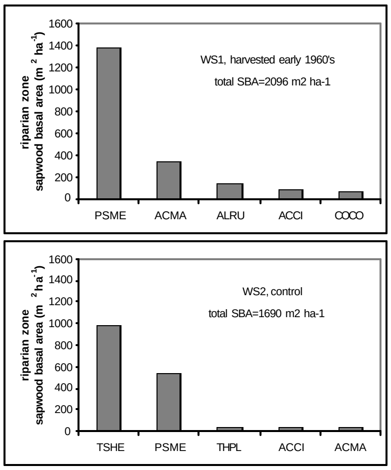


Fig. 8. Sapwood basal area by species in riparian areas of WS1 and WS2.

Water use on a unit ground area basis was calculated as the product of sap flow per unit sapwood area and total sapwood basal area. In order to calculate total vegetation water use, we conducted vegetation surveys in the "riparian area" of both WS1 and WS2.

The total sapwood area and species distribution of that area, in addition to physiological differences in different species and different size classes of trees, result in much greater water use by woody vegetation in WS1 compared with WS2. The total sapwood basal area of all woody vegetation is about 25% greater in the regenerating stand compared with the old growth forest. Also, hardwood species are a much more important component in the regenerating forest (34% of sapwood basal area) compared with the old-growth forest (7%) (Fig. 8). In measurements we conducted during the summer of 1999, we found that transpiration per unit sapwood area was significantly higher in red alder compared with Douglas-fir, and also that the transpiration of the broadleaf species remained relatively constant through the summer season while that of the conifer decreased by nearly ½ between early July and mid-September.

With our current measurements (ignoring understory species and also ignoring hardwoods in the old growth stand) water use by woody vegetation in the riparian zone of WS1 appears to be much higher than in WS2 (Fig. 9).

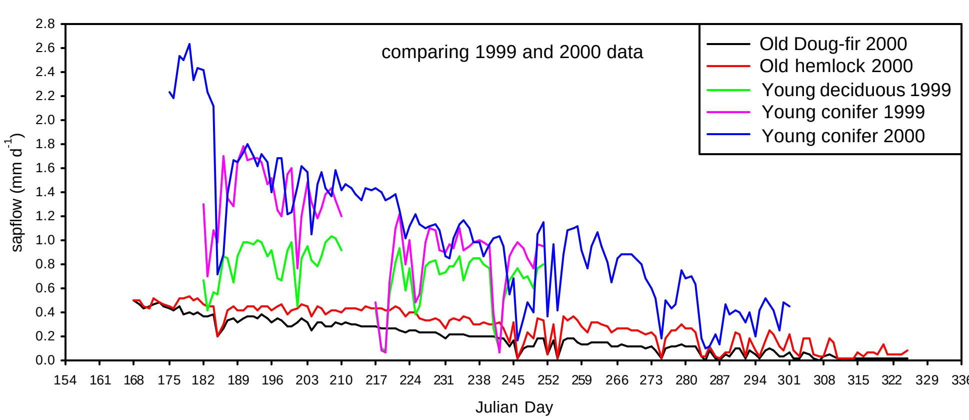


Fig. 9. Yearly and age-related comparisons. The old-growth trees in Watershed 2 utilize much less water per unit ground area than young, 40-year-old trees in the adjacent Watershed 1. Note that sap flow rates in young conifers (based on 7 Douglas-fir trees in a transect similar to that of Watershed 2) were similar in 1999 and 2000. There are relatively fewer deciduous trees in Watershed 1 than conifers, however sap flow rate do not decline as rapidly through the summer (based on 7 red alder trees in a transect similar to that of Watershed 2, located near the 7 Douglas-fir trees).

The apparent differences in vegetation water use in riparian zones of WS1 vs. WS2 appear to be much greater than the differences that appear in the stream flow records (although we have not yet done this comparison quantitatively).

We haven't measured sapflow of any understory species at HJA, but at Wind River we've measured vine maple, and the rates are surprisingly high for an understory species (Fig. 10). We think it is important to begin incorporating understory species in calculations for the HJA.

Fig. 10. Diurnal trends in sapflow of important species in an old-growth stand at Wind River, WA.