WRRI Student Grant Report

Sap Flow Project

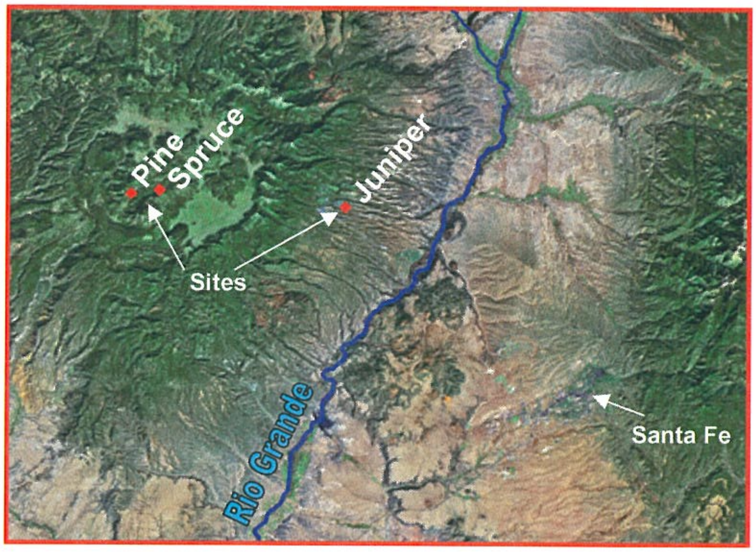
By
Sue White

WRRI Summary Report
4/26/2006

Introduction:

This study measured overstory transpiration and canopy conductance in two ecosystems in New Mexico located across a dramatic climatic gradient shown in *Figure 1*. This project was conducted with the objective to examine environmental and physiological mechanisms by which vegetation impacts the hydrologic cycle of the Rio Grande Basin (*Figure 1*). Sap flow was measured using the heat dissipation technique (Granier, 1987) on mature juniper (*Juniperus monosperma*), ponderosa pine (*Pinus ponderosa*), and spruce (*Picea englemannii*) trees located within 40 km of each other over a six-day period (September 16-21, 2005 or DOY 259-264). Whole tree leaf area:sapwood area ratios and sapwood area:ground area ratios were also measured to assess how structural shifts at the whole-tree and stand level impact stand-level transpiration.

Figure 1 Site Locations



Methodology:

The field sites are located at Los Alamos National Laboratory (juniper site) and within the neighboring Valles Caldera National Preserve (pine and spruce sites). The site elevations are as follows: (1) juniper = 2200m; (2) spruce = 2017m; and (3) pine = 2500m. Transpiration per unit sapwood area, E_S (mols m^{-2} s^{-1}), transpiration per unit leaf area, E_l (mmols m^{-2} s^{-1}), and transpiration per unit ground area, E_g (mmols m^{-2} s^{-1}), were calculated using methods from Granier (1987) and Ewers (2001, 2005). Analysis of stomatal sensitivity (the response of G_S to VPD as a function of G_S at a reference point of 0.6 kPa VPD) was done according to Oren et al. (1999). Ten trees per site were measured on both the north and south face at the pine and spruce sites and faces were averaged arithmetically. Junipers are a multi-stemmed species, so five individuals were measured, which included two stems per individual at the juniper site. Meteorological data was measured at the juniper site, and nearby meteorological stations within the Valles Caldera were used for spruce and pine data. Tree-level and plot-level allometric data were obtained through harvest of ten individual trees at each site in the summer of 2005. Leaf area and sapwood area of the harvested trees were determined as per McDowell et al. (*in press*). Tree cores were collected using increment borers to determine sapwood areas.

Study Limitations:

The study was intended to run through the summer, fall, and winter of 2005. Site set-up was completed in August because site complications and malfunctions delayed the system analysis period. Animal equipment destruction also delayed final site completion. Once the sites were up and running, the Valles Caldera sites (pine and spruce sites) were run by solar collectors. Frequent cloud cover restricted battery recharge and caused the systems to shut down frequently, which resulted in data loss during down time. Thus, the best window of data for all sites was the six days analyzed in this report. Site modifications will be in effect summer 2006 to allow for continuous data collection at all three sites.

Conclusions:

The driest site species, juniper, has the highest transpiration per unit sapwood area but the lowest transpiration per unit leaf area or ground area due to differences in sapwood area per unit leaf area and sapwood area per unit ground area (*Table 1; Figures 2,3,4,5*). This balance between transpiration per unit sapwood area and per unit leaf area is consistent with the notion of hydraulic adjustments at the tree and stand scale that minimize cavitation. Also, VPD is a strong driver of transpiration and stomatal conductance both within and across the sites (*Figures 6 & 7*).

Graphs:

Key:

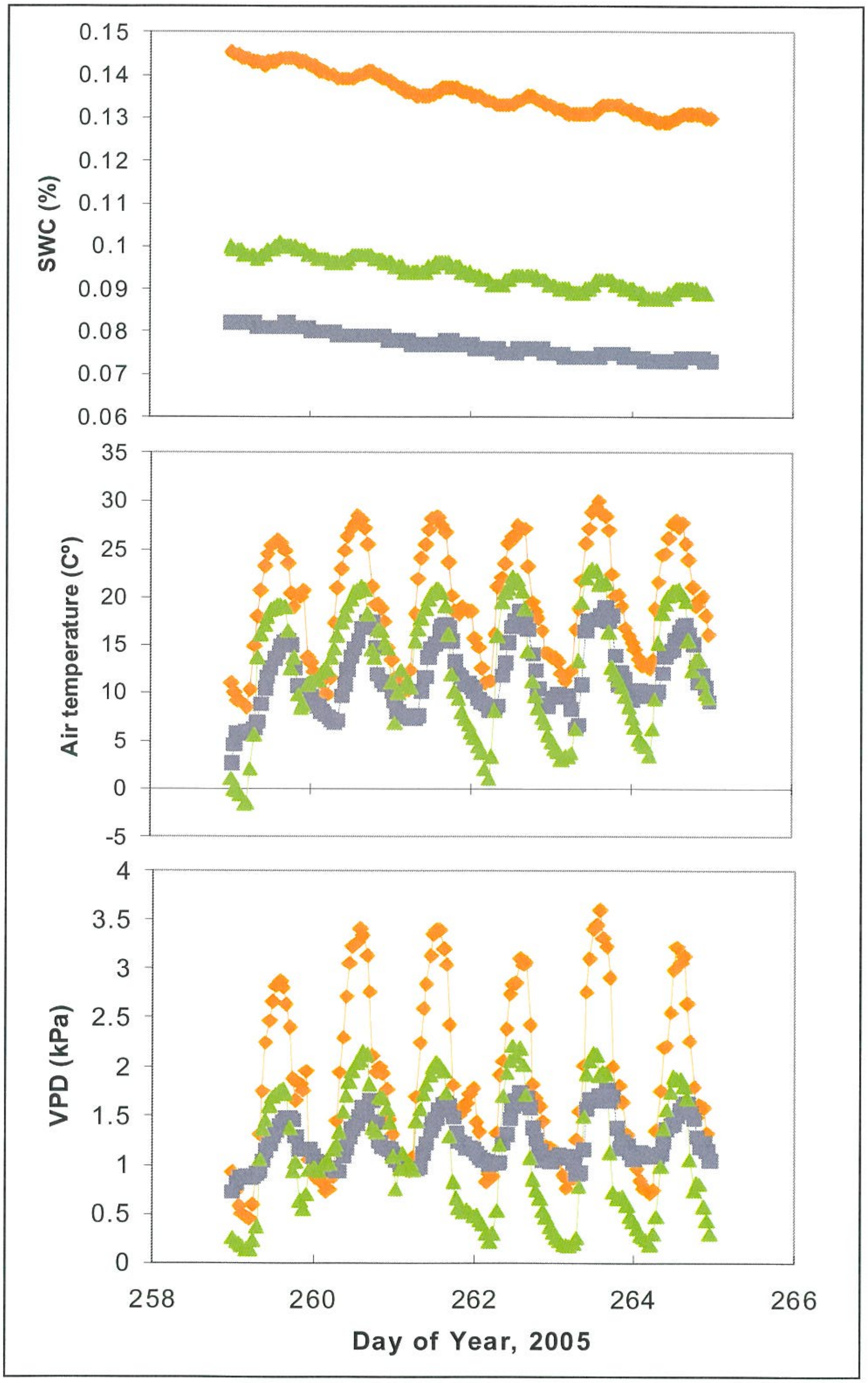
Symbol	Description	Units
	Juniper, *Juniperous monosperma*	
	Pine, *Pinus ponderosa*	
	Spruce, *Picea englemannii*	
E_s	Evapotranspiration per unit sapwood area	mols m^{-2} s^{-1}
E_l	Evapotranspiration per unit leaf area	mmols m^{-2} s^{-1}
E_g	Evapotranspiration per ground leaf area	mmols m^{-2} s^{-1}
G_s	Stomatal conductance	mols m^{-2} s^{-1}
VPD	Vapor Pressure Deficit	kPa
A_s:A_g	Ratio of sapwood area to ground area	cm^2 m^{-2}
A_s:A_l	Ratio of sapwood area to leaf area	m^2 ha^{-1}

Table 1 Site Differences

Species	A_s:A_g	A_s:A_l	Density	Basal Area	LAI	Mean Tree Ht	MAP
Juniperous monosperma	4.5	4.5	834	11	1.0 (1.5*)	2.7	40
Pinus ponderosa	47.5	18.2	1041	50	2.6	21.3	59.8
Picea englemannii	34	10	792	45	3.4	19.6	92.9

Note: density=# *stems/ha*; basal area=m^2/*ha*; leaf area index (LAI)=m^2 *leaf area*/m^2 *ground area*; & tree height=*m*.
*LAI of *J. monosperma* is 1.5 when the understory is included in the analysis.

Figure 2 Meteorological data, including soil water content*
(upper panel), air temperature (middle panel) and vapor pressure deficit (lower panel)



* Mean annual precipitation: 40 cm, 60 cm, and 93 cm for the juniper, pine and spruce sites, respectively.

Figure 3 Daily mean E_s

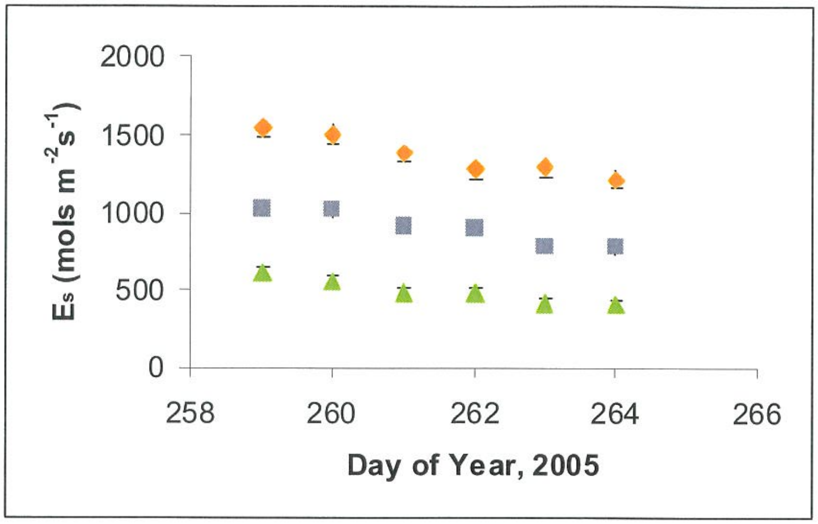


Figure 4 Daily mean E_l

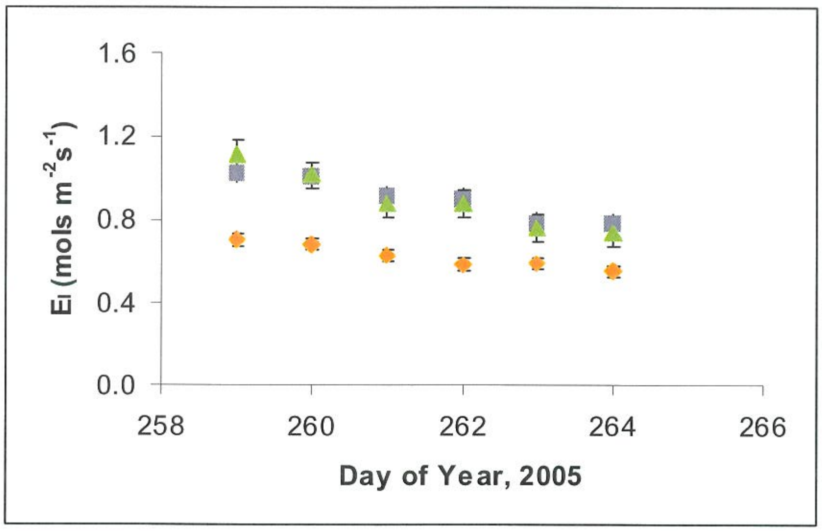


Figure 5 Daily mean E_s

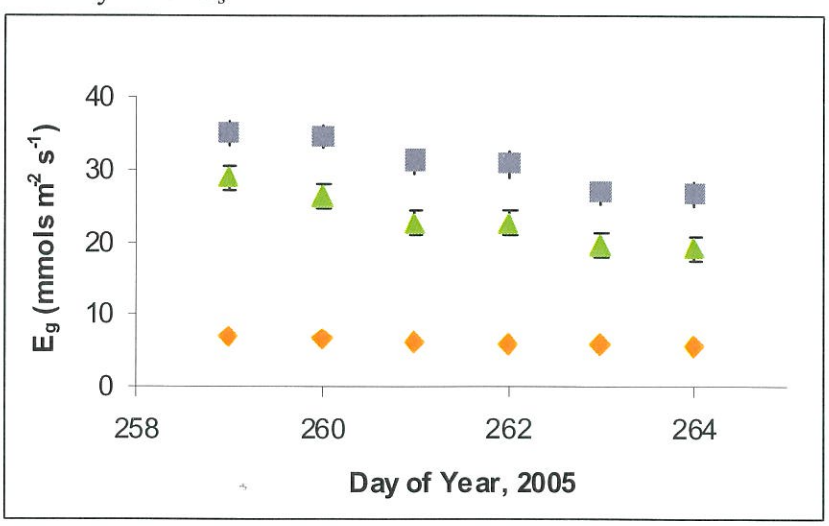


Figure 6 Daily maximum E_l vs. VPD

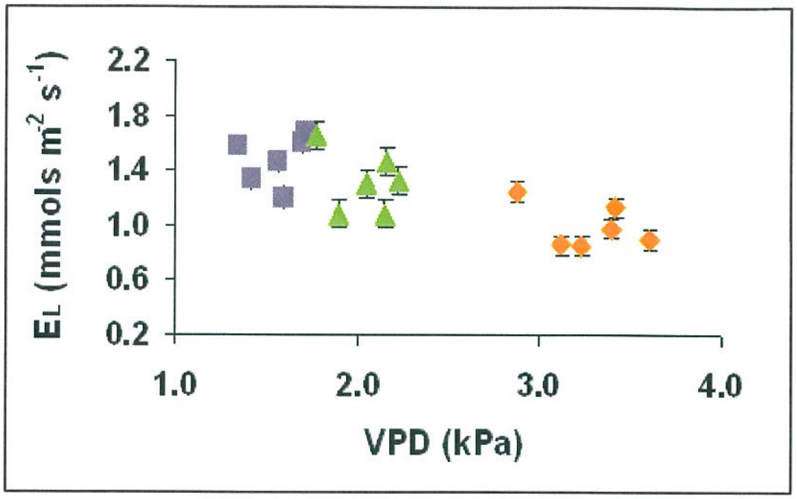
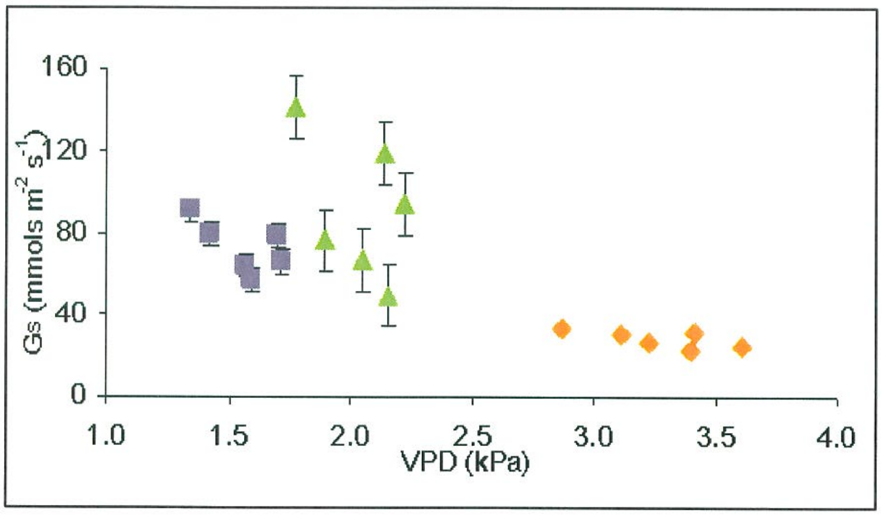


Figure 7 Daily mean G_s vs. VPD



WRRI Support:

This project was made possible by funding from the WRRI student grant. Funds paid for field and repair equipment for the Valles Caldera ponderosa and spruce sites. It also allowed for the principal investigator to work through the school year. Without WRRI support, this project would not have been completed. Due to complications and set backs at the sites, good data was not collected for all three sites until after the fall semester began. Thus, data collection and analysis was not performed until well into the fall semester. All of the work performed during the fall and spring semesters was funded solely by the WRRI grant. Special thanks to WRRI for support of this research. The project has also motivated the primary investigator to peruse ecological studies for her master's degree at the University of New Mexico after receiving her B.S. in Environmental Engineering at New Mexico Tech this May. Without your support, she would not have found the love of ecology at this point in her life.

Literature Cited:

Ewers B.E. et al. (2001a) Estimating maximum mean canopy stomatal conductance for use in models. *Canadian Journal of Forest Research* ***31,*** 198-207.

Ewers B.E. et al. (2005) Effect of stand age and tree species on canopy transpiration and average stomatal conductance of boreal forests. *Plant, Cell and Environment* ***28***, 660-678.

Granier A. (1997) Evaluation of transpiration in a Douglas-fir stand by means of sap flow measurements. *Tree Physiology* ***3***, 309-320.

Daley M.J., Phillips N.G. (2005) Interspecific variation in nighttime transpiration and stomatal conductance in a mixed New England deciduous forest. *Tree Physiology (In Press).*

McDowell N.G., H.A. Adams, J.D. Bailey, M. Hess, and T.E. Kolb. (2005) Homeostatic maintenance of gas exchange in ponderosa pine: a 40-year restoration thinning experiment. *Ecological Applications. (In press)*

Oren R. et al. (1999) Survey and synthesis of intra- and interspecific variation in stomatal sensitivity to vapor pressure deficit. *Plant, Cell and Environment* ***22***, 1515-1526.

Acknowledgements:

The author wishes to thank the Water Resources Research Institute, Los Alamos National Laboratory, and the Institute of Geophysics and Planetary Physics for the opportunity to conduct this research. Many thanks also go to the many people who have supported this project including: Nate McDowell, Karen Brown, Heath Powers, Eric Small, Paul Brooks, Phillip Jacobsen, Will Pockman, Nathan Phillips, Mike Daley, Toti Larson, Laura Marshall, Clif Meyer, Ted Hickey, Valles Caldera National Preserve, Los Alamos High School Cross-Country team, and Shawn West♥.