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P1.8 SAP FLOW AND TRANSPIRATION OF OLD LODGEPOLE PINE TREES

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1. INTRODUCTION

The Upper Penticton Creek Watershed Experiment is a long-term paired-watershed study investigating the effects of forest harvesting on water quantity and quality. Measurements of transpiration are required to help parameterize and test a watershed scale distributed hydrology-soil-vegetation model for complex terrain. The research took place in the 240 Creek watershed (49 39 25N, 119 24 10W) at 1630 m elevation in the drier Engelmann Spruce – Subalpine Fir Zone. Permanent snow cover exists from late October until mid May. Snowmelt and early summer rainfall keep the soil moist until mid August and September. Mean annual precipitation is about 800 mm. Summer is generally cool with daily averages of 8 to 12°C and maximums of 10 to 25°C. The daily maximum vapour pressure deficit rarely exceed 3 kPa.

This paper focuses on the measurement of tree transpiration using thermal dissipation probes. These data are then used to obtain an estimate of areal tree transpiration. These data are then incorporated into a water balance calculation along with measured rainfall interception and soil water content and modelled drainage to determine understory evaporation.

2. METHODS

Site description: The forest consists of 125-year-old lodgepole pine, 20 to 25 m tall. Stand density is 800 stems ha^{-1}, canopy cover 43% and plant area index is 2.5. 34% of the trees have a diameter at 1.5 m of <0.2 m, 48% 0.2-0.3 m and 18% >0.3 m. The understory is a mixture of trees less than 3 m tall, lichens, moss and grouseberry. The soil is a sandy loam, eluviated dystric brunisol, with a coarse fragment content of 30 to 45% below the 0.2 m depth and plant roots to 0.6 m.

Tree transpiration: Thermal dissipation probes (Dynamax Inc., TDP-30) were used in determining sap flow from 13 June to 31 October 2001 and 17 April to 18 September 2001. Five trees had thermal dissipation probe on the north and south side of the tree, and 4 others had probes only in the north side. 15-minute average temperature differences were collected, plus the daily maximum difference. Cores were taken from the north and south side of trees adjacent to the probe to determine sapwood width and area. Corrections were made (Clearwater *et al.* 1999) to the temperature difference when sapwood thickness was less than the length of the probe. Stand density and stem diameter distribution data were used to determine weightings to convert sap flow to areal tree transpiration.

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Weather data: Hourly measurements of solar radiation, air temperature, air humidity, wind speed and rainfall were made in an adjacent clearcut. Air temperature and humidity were measured at 2 m above the forest floor.

Rainfall interception: Interception loss is the difference between above-canopy rainfall and the sum of throughfall and stemflow. Five throughfall troughs and 5 stemflow collectors were continuously monitored using a data logger (Spittlehouse 1998).

Soil water balance: Soil water content was measured manually using time domain reflectometry (Spittlehouse 2000). Measurements of average water content from the soil surface (0 m) to 0.15 m, 0 to 0.3 m and 0 to 0.5 m were made every 7 to 12 days from May to October at twenty locations on a 100 m transect.

Drainage was calculated using a drainage as a function of storage model (Spittlehouse and Black 1981). Laboratory measurements on the fine fraction of the soil were used with the stone content and porosity data from bulk samples to give retention and drainage equations corrected for coarse fragment content.

Evaporation from the soil surface and transpiration of the understory equals $\Delta S+R-I-T-D$. In this equation, T is areal tree transpiration, D is drainage, R is rainfall, I is interception and ΔS is the change in soil water content between the measurement periods.

3. RESULTS

3.1 *Intra- and inter-tree comparison of sap flow*

The diurnal course of sap flow followed the diurnal courses of solar radiation and vapour pressure deficit. Nighttime flows were small. Sap flow was zero during rainy periods. Three diurnal patterns of response were observed. The largest two trees had the highest sap velocity and sap flow volume and peaked in the late afternoon. The second group had a lower flow and peak in the early afternoon. The third group has the lowest flow with minimal flow in the morning and peaked in the late afternoon. Flow measured on the north and south sides of a tree show the same pattern and flow on the north side was slightly lower than on the south side.

Daily sap flow for the trees with diameter >0.3 m had maximum flows on sunny days of over 50 L d^{-1}. These were 3 to 4 times that of the other seven smaller trees (Figure 1). The large trees were not crowded by the other trees and had larger crowns. The variation between the seven smaller trees was independent of tree size. Daily sap flow showed linear or slightly non-linear relationships between trees with R^2 > 0.94 in most cases. North and south side flows showed similar excellent agreement. Soil drying below –0.5 MPa reduced maximum daily flow by about 30% during late August and early September. Sap flow was reduced on days with air temperature below zero. There was significant flow on days in late April and early May 2001 when there was a 0.5-m deep melting snow pack.

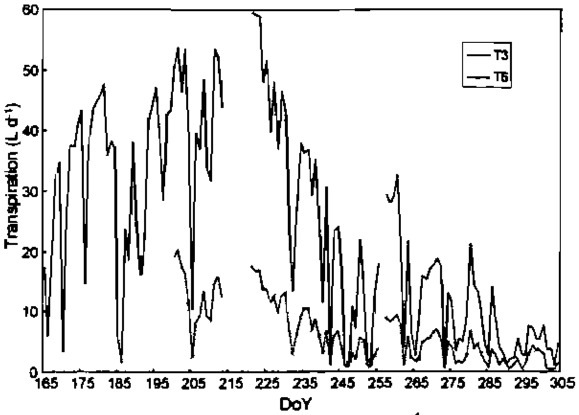

Figure 1. Daily tree transpiration (L d^{-1}) for a 0.35-m diameter tree (T3) and a 0.2-m diameter tree (T6).

3.2 Areal tree transpiration

Daily areal tree transpiration was calculated using data for all the trees. The flow for the north side of the tree was assumed to represent the whole tree where only the north side was measured. An average flow was calculated for each diameter classes. These values were then weighted by the fraction of the diameter class in the stand and multiplied by stand density to give tree transpiration. On sunny days with vapour pressure deficits over 2 kPa, maximum daily areal transpiration rates were 1.4 to 1.8 mm d^{-1}. The dry soil and cool conditions after day 229 reduced transpiration (Figure 2). The trees with a diameter >0.3 m constitute only 18% of the stand but contribute about 50% of the water to areal tree transpiration. Varying the weightings gave an error estimate of ±20% for areal tree transpiration.

3.3 Site water balance

Mean daily areal tree transpiration was between 1 and 1.5 mm d^{-1} in mid summer. This decrease to about 0.5 mm d^{-1} in late August and September when soil water potential dropped below –0.5 MPa and remained low in the cool late September and October weather. Average below canopy evaporation varied from 0.7 to 0.2 mm d^{-1}. Mean daily evaporation varied from 2.4 mm d^{-1} in June to August to 1 mm d^{-1} in late September. The trees and the below canopy contributed 42% and 25%, respectively, of the total evaporation (239 mm). 28% of the rainfall was interception and this comprised 33% of the total evaporation. Drainage was 27 mm.

4. CONCLUSIONS

Areal transpiration rates are at the lower end of values for forests, particularly in the temperature zone (Kelliher *et al.* 1993). However, many of the lodgepole pine trees have only a small amount of foliage and the trees are over a 125 years old. Hubbard *et al.* (1999) suggest that old trees are subject to reduced hydraulic conductance between the roots and leaves which can significantly reduce transpiration rates. The ratio of understory/soil to stand evaporation is within the range of data reported by Black and Kelliher (1989).

5. ACKNOWLEDGMENTS

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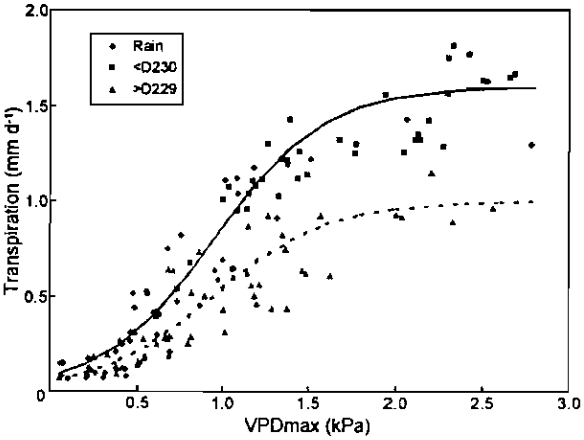

Figure 2. Areal tree transpiration (mm d^{-1}) and daily maximum vapour pressure deficit (kPa) on days 165 to 229 (■), days 230 to 304 (▲) and days with rain (◆).