Sap Flux Density in Peatland Species:

Root and Branch Water Conductance Under Simulated Drought Conditions

Claire A. Campbell, Furman University, 29613; Jeff Warren, Oak Ridge National Laboratory, 37830

Introduction

ORNL's Ecosystem Sciences Group is a participant in Spruce and Peatland Response Under Climatic Exposure (SPRUCE), studying the effects of elevated CO_2 and soil and air warming, on a peat bog in the Marcell Forest, MN. Vegetation is studied to determine characteristics of water conductance in roots and sapwood in 20-40 year-old black spruce (*Picea mariana*) trees. To estimate wood conductivity we measured water flow gravimetrically and compared readings with thermal dissipation probes (TDP) on various species from the bog. TDPs measure flux through sap wood based on voltage using Andre Granier's equation, developed in 1985 (Lu et al. 2004). Recent research has uncovered discrepancies with the application of the Granier equation to certain species (Steppe et al. 2010). Using TDPs and gravimetric readings simultaneously, we can determine the accuracy of Granier's equation. Our findings conclude that TDPs may be inaccurate in *Picea* because of the limited sap wood area in these trees. Also, root conductance measurements showed that bog trees are capable of withstanding drought conditions.

Research Questions

Research Question 1: According to the Granier equation thermal dissipation probes provide scientists with sap flux in field studies where gravimetric measurements are impossible. In spruce trees, what is the correlation between gravimetric and Granier sap flux density?

Research Question 2: How much drought (as applied pressure) can various species of boreal bog vegetation withstand without losing conductivity?

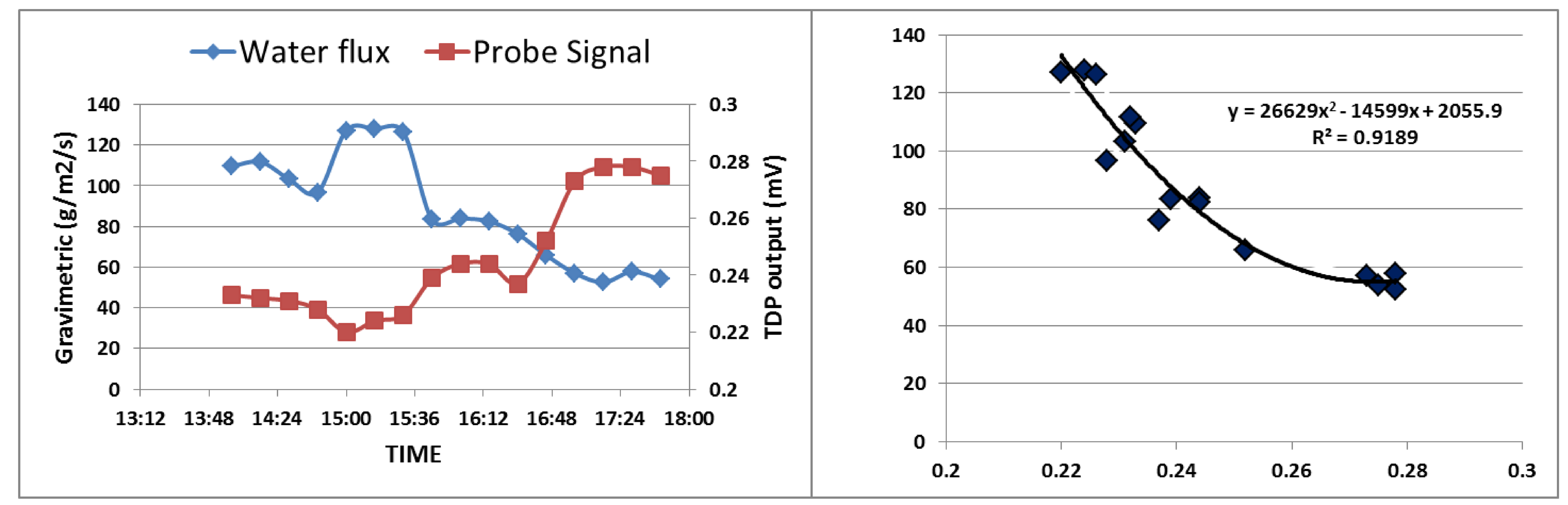
Methods

- Samples were collected in the bog, stored on ice, and rehydrated in the laboratory.
- Thermal dissipation probes from PlantSensors™ (Nakara, Australia) which use Granier's empirical equation to calculate sap flux were inserted into the larger trunks.
- A pressure head of acidified water was connected to the samples allowing water flow through the trunks. Water was collected in 15 or 30 minute intervals.
- Sap flux was determined as grams H_2O/sapwood area/time. This was compared to the Granier Equation used to extrapolate sap flux.
- To determine sapwood area, trunks were dyed and thin sections were processed using ImageJ software.
- To determine root water conductivity under drying conditions, a pressure chamber using N gas was used to progressively remove xylem water.
- Volumetric measurements of root water flux were measured in pipets, as 0.01 mL per time increments.

Results

Sap Wood Area Sample

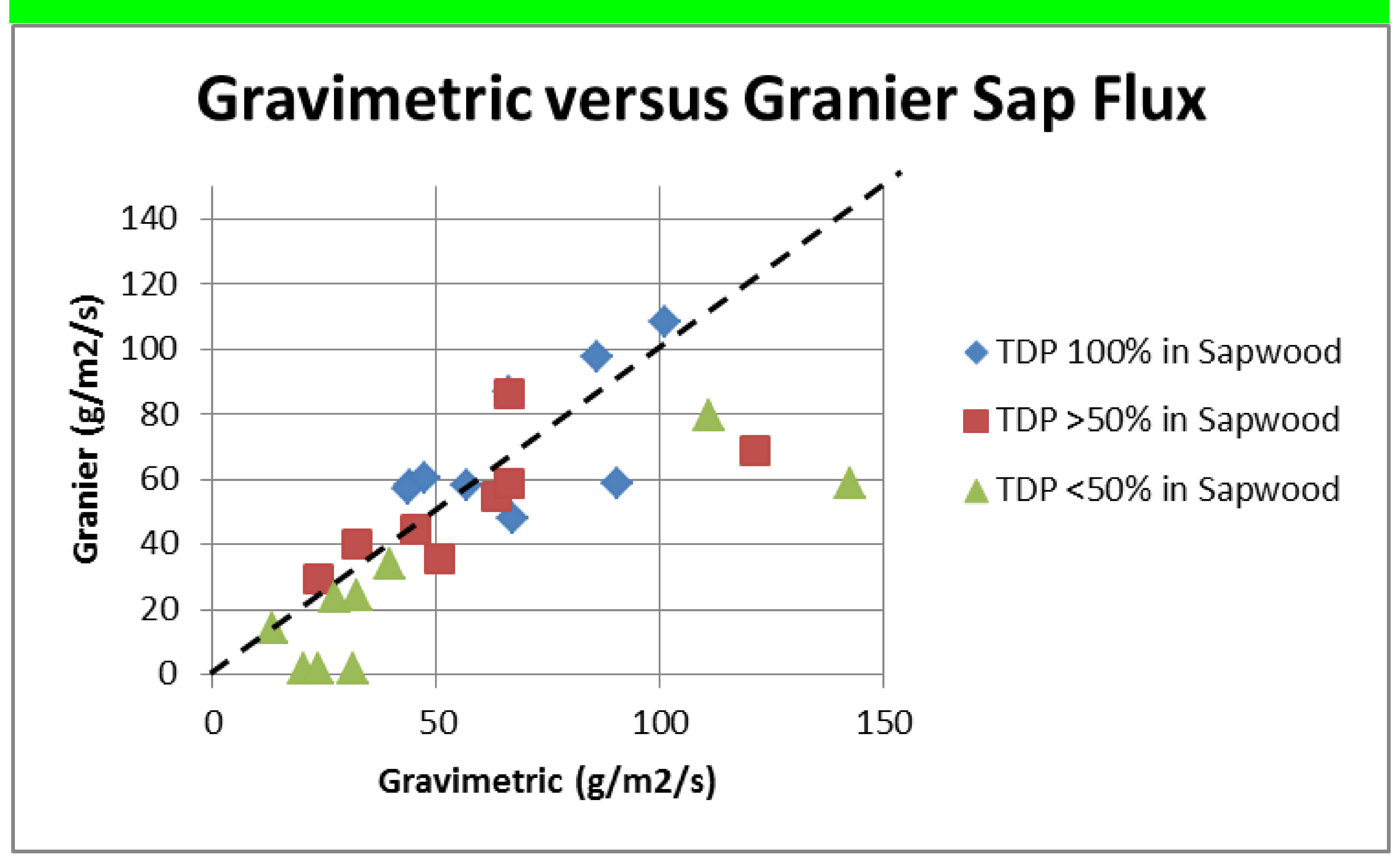
Trunk Conductance



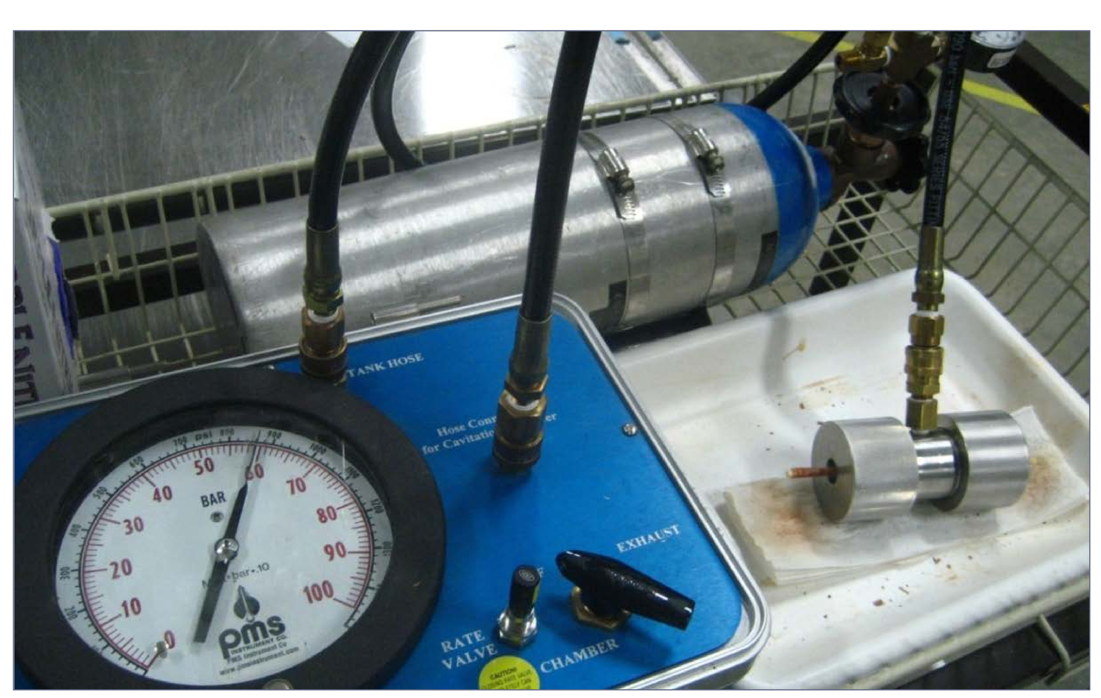
The pressure head was adjusted resulting in variable flux, which is noticeable as stepwise changes both in gravimetric (measured flux) and mV (TDP) readings over time. These steps created averages which were then used to determine the points on the graph below.

Sap Flux Probes

Granier's Equation: $$Flux = 118.99 * 10^{-6} * \left(\frac{\Delta Vmax - \Delta V}{\Delta V}\right)^{1.231}$$



TDPs inserted in a sample with variable water pressure head.



Pressure chamber for Small Roots

Root Conductance

Species	Maximum Sap Flux (g/s)	50% Loss of Conductivity Reached:
Picea	0.000557	3.46 MPa
Larix	0.00252	2.56 MPa

Chamaedaphne and *Ledum* roots were also tested with almost no results. The flow rates were similar on an area basis, but the pressure chamber technique was not conducive for measurable flux.

Analysis

Trunk Analysis

- Flow rates were generally between 25-75 g/m^2/s, with higher rates correlating to larger sapwood area.
- Water potential gradients ranged from 0-240 cm with an average of 60-90 cm.

Validating Granier's Sap Flux Equation

- The thermal dissipation probes were not able to accurately measure sap flow in *Picea* because of limited sapwood area.
- Some error was related to leaking gravimetric measurements from a faulty seal on the system.
- We found that if the length of the probe was too long for the sapwood area radius, false readings based on the probe's insertion into non-hydroactive heartwood occurred. In trees with a diameter greater than 5.2 cm, 1 cm TDPs may be able to span sapwood and give the accurate readings.

TDP error was evident in cross-sectional cuts, showing the probes exceeding the sap wood area on several samples.

Root Analysis

Picea and *Larix* roots showed ample conductance rates under stressed conditions.

- Both *Picea* and *Larix* showed high resistance to cavitation (< 50% loss of conductivity) until after the maximum pressure they would be exposed to in the field (~2.2 MPa). *Picea* reached 50% PLC at 3.46 MPa and *Larix* reached the same level at 2.56 MPa.

References

Lu et al, "Granier's Thermal Dissipation Probe (TDP) Method for Measuring Sap Flow in Trees: Theory and Practice," Acta Botanica Sinica 46 (2004): 631-646.

Steppe et al, "A Comparison of sap flux density using thermal dissipation, heat pulse velocity and heat field deformation methods," Agriculture and Forest Meteorology 150 (2010): 1046-1056.

Contact Information

Claire Campbell
Furman University
Earth and Environmental Science
claire.campbell2123@furman.edu

Jeff Warren
Oak Ridge National Laboratory
Environmental Science Division:
Ecosystem Sciences Group
Warrenjm@ornl.gov

Updated 02-2012 by JMW