3. Tier III Sap Flux Network: New Efforts to Facilitate Region-wide Integration

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The analysis of Tier III sap flux data provides mechanistic explanations for variability observed in tree growth and tree carbon sequestration across regions, management and climate scenarios. Synthesizing results across all sites is a key output in translating field research to models, which can be used to help forest managers and policy makers understand how planted pine may respond to future management and climate conditions.

Since mid-2012, the PINEMAP sap flux monitoring network has collected more than 18 million data points on water use and environmental conditions across the four Tier III sites in Georgia, Florida, Virginia, and Oklahoma. As PINEMAP enters its final year, the challenge will be to assimilate these data, along with the 600,000-point monthly data stream, into a cross-site analysis that accounts for variability and uncertainties of scaling from individual tree measurements to the larger scale necessary for assessing climate change impacts on regional productivity. PINEMAP members have already begun several additional lines of data collection and analysis that will contribute to making this integration effort a success (see articles 4 and 5 in this report). Here we discuss three efforts to improve scaling precision: remote sensing of seasonal changes in leaf area, radial profiles of sap flux, and investigations of root area and function.

Remote Sensing of Leaf Area Index

Knowing the amount of leaf area per unit ground area (leaf area index or LAI) in a forest is critical for accurately modeling carbon uptake, water loss, and productivity. PINEMAP researchers periodically measure LAI in experimental plots, but pine LAI is highly variable within a year, so it can be challenging to interpolate LAI values between measurement periods. In addition, because the Tier III sites are distributed across the entire southeastern U.S., the timing of leaf area expansion and loss is expected to differ considerably between sites. To provide consistent estimates of seasonal LAI variation across sites, PINEMAP members have begun analyzing remotely sensed data from the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) satellite that are available for the 2003–2012 period from the Web-Enabled Landsat Data Project (https://landsat.usgs.gov/WELD.php). Using the approach of Flores et al. (2006), minimum and maximum LAI dates were determined from these data and used to inform the interpolation between ground-based measurements in each plot. Because these stands are relatively young and had pre-experimental understory vegetation control, this is an ideal situation for a remote sensing approach. Intra-annual curves fitted by harmonic regression (Brooks et al., 2012) may also be used to estimate seasonal LAI variation.

Radial Profiles of Sap Flux

The original experimental design of the Tier III monitoring network included five sap flux sensors per plot installed at 0-2 cm sapwood depths. Because tree trunks grow from cambium cells sandwiched between the bark and sapwood, these measurements represent flow rates in the youngest and usually most conductive wood. Xylem function declines with sapwood depth, so deeper, older sapwood has slower sap flux rates. Since outer sapwood in trees at Tier III sites was grown under the treatments imposed in 2012, but deeper sapwood was not, the radial pattern may differ between treatments. Additional sensors were installed at 2-4 cm and 4-6 cm sapwood depths in 2014 at all four Tier III sites to quantify these radial patterns and account for them when scaling the sap flux measurements up to total stand water use. As expected, sap flux declined with sapwood depth at the Florida site (Figure 3.1).

Sap flow sensors at the PINEMAP Tier III throughfall reduction x fertilization site in Taylor County, Florida. Photo by Jessica Ireland.

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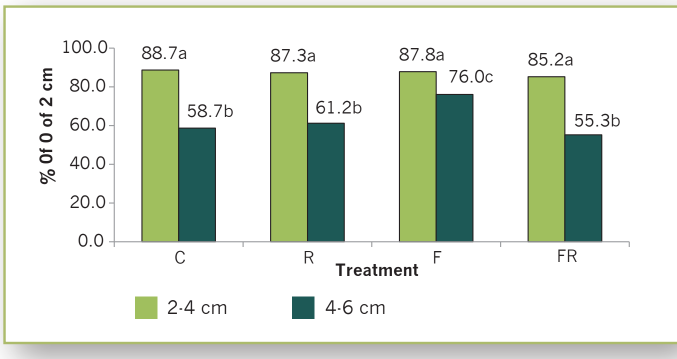

Figure 3.1. Sap flow rates at 2-4 cm and 4-6 cm depths at Florida Tier III site expressed as a percentage of sap flow at 0-2 cm depth for control (C), throughfall reduction (R), fertilization (F), and throughfall reduction and fertilization (FR) treatments. Percentage values shown above each bar; values followed by the same letter are not significantly different (p = 0.05).

Root Area and Function

Data from the Virginia site (Ward et al., in review) show greater declines in stomatal conductance under the combined treatment of fertilization and throughfall reduction than either treatment alone (Figure 3.2). This decline in stomatal conductance without significant difference in LAI suggests that resistance to water flow has increased in some other component of the hydraulic pathway to the leaves, most plausibly the roots. This may occur through changes in root area, root spatial distribution and/or resistance to water flow in root xylem. Accordingly, PINEMAP investigators at this site will be examining all three of these components of root function during the 2015 growing season to identify mechanisms underlying the observed patterns of water use. Knowing which mechanisms affect water use can help to improve regional models and may inform forest management recommendations in a variable climate.

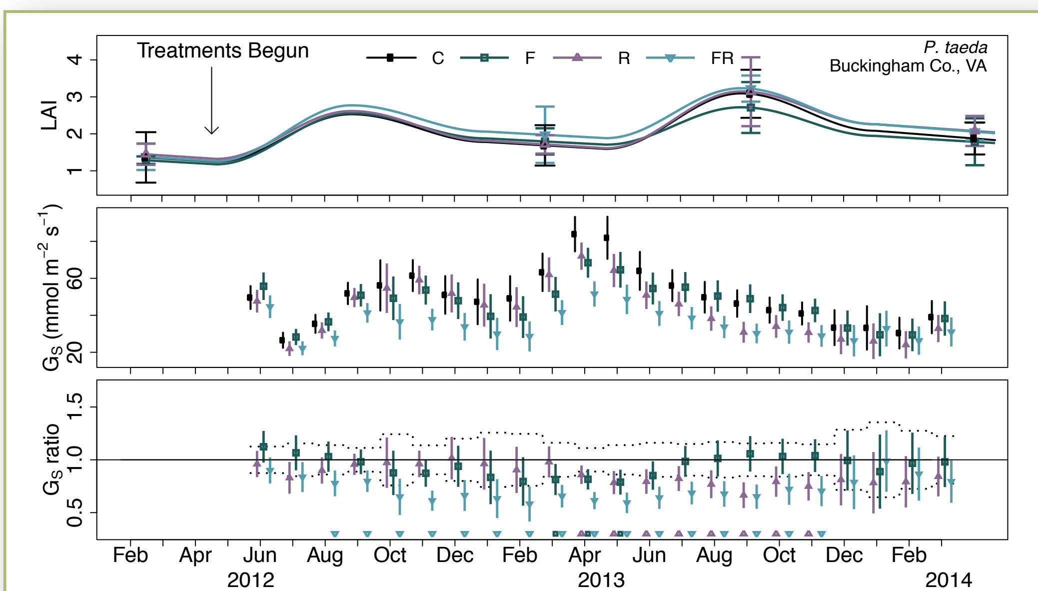

Figure 3.2. Estimated monthly daytime canopy-averaged stomatal conductance (GS, mmol m-2 leaf area s-1) for control (C), throughfall reduction (R), fertilization (F), and throughfall reduction and fertilization (FR) treatments at Virginia Tier III site (top) and the ratio of the GS in each treatment to the control value (bottom), where a 95% credible interval of the control is indicated by the dotted line and by error bars for treatment values. Small symbols at the bottom of the panel represent treatments where monthly value was different from the control with 95% confidence using a normal parametric bootstrap of model posterior values.