Aquaporin-Mediated Reduction in Root Hydraulic Conductivity Impacts Whole Stand Water Use and Carbon Assimilation: Scaling and Modeling the Effect of Sea Level Rise from Roots to the Ecosystem

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Due to a combination of thermal expansion of seawater and melting of polar ice sheets, global sea level rose 0.17 m over the 20th century and is projected to rise by at least 0.45 m by 2100. Unmanaged ecosystems along the Atlantic and Gulf coastal plains are especially vulnerable to sea level rise (SLR). In addition to constant flooding, SLR is expected to foster high salinities into tributary freshwater areas of the coastal zone. The current understanding of plant adjustment and tolerance to flooding and salinity is that they affect the plant conducting system in order to maximize water uptake. Although, understanding plant responses to SLR requires the determination of what affects physiological responses to the stressors, there are no studies that have focused on variation in plant hydraulic traits. Water flow in the soil-plant-atmosphere continuum is determined by the whole-tree hydraulic conductance of soil and plant tissues (Ktree), which characterizes the capacity of the plant at moving water. We showed that 50-60% of the whole-plant hydraulic resistance (1/Ktree) is located in the root system (1/Ktroot), stressing the outstanding importance of this organ within the flow path. In addition, recent work demonstrated that aquaporin (AQP = membrane protein) activity is the primary factor determining radial conductivity of roots in response to a large variety of environmental factors. Using a high pressure flow meter and hydroxyl radical inhibition of AQPs, we have found that flooding and salinity reduced Kroot and AQP activity of roots of P. taeda grown in a controlled greenhouse. Our study indicated that water transport by AQPs accounted for 20% to 85% of the overall water transport. These results also showed that the inhibition of AQP was higher in control trees, indicating that flooding and salinity reduced the AQP contribution to Kroot. AQP-induced inhibition of Kroot affected plant water transport by reducing Ktree by more than 28%, and stomatal conductance by 25% under flooded condition and 55% under flooded +salt condition. Furthermore significant reduction in Kroot and thus Ktree caused plants to transpire less, significantly altering microclimatic conditions in the canopy boundary layer. Using a mechanistic soil-plant-atmosphere model (SPA) and our empirical data we predicted that SLR would reduce water uptake by 55% and gross ecosystem productivity by 31%. Those predictions were consistent with the reduction in tree growth measured in the field and with the measured water (sap flow) and carbon fluxes (eddy covariance).