Canopy water use efficiency before, during and after gypsy moth attack in an upland forest in the New Jersey Pine Barrens

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The New Jersey Pine Barrens are a fire adapted, ecosystem in central-south New Jersey. The soil is sandy, and thus well-drained and nutrient poor. Due to fire suppression and thus natural succession, the upland forest consists approximately to one third of oak/pine forests that are susceptible to gypsy moth infestation and drought. This upland oak/pine stand experienced a gypsy moth infestation in 2007 and a very severe drought in 2010 that resulted in a 30% mortality of larger oak trees. Such events cause changes in water, nutrient and light availability, which in turn affect the canopy water use efficiency and carbon uptake. Here, we present sap flow measurements over ten years from 2005 to 2014 with the heat balance and heat dissipation method and leaf level photosynthesis measurements from 2006, 2010, and 2012-2014 using a Licor 6400 XT. Parallel eddy covariance measurements were used to estimate evapotranspiration over the 2004 to 2014 time period. Applying these measurements with the Canopy Conductance Constrained Carbon Assimilation model (4CA), we demonstrate the changes in canopy water use efficiency over this ten-year period.

Over the ten-year period, canopy water use declined due to mortality and has as of yet, not rebound to pre-defoliation levels. However, water use has not proportionally dropped to mortality, due to compensation of surviving trees, mostly white oak species and pines, whereby red oak species declined. Moreover, water use efficiency dropped throughout the study period by approximately 20% mostly due to higher water availability of the surviving trees compared to commensurate carbon uptake. The photosynthetic capacity, however, has increased by 25% from 2006 to 2013, mostly due to higher light availability and partially higher nitrogen content in the leaves. Thus, although mortality and defoliation increase availability of water and light, the surviving population does not increase their water use efficiency, but rather shift to a more wasteful water resource management. Eddy flux measurements indicate that while evapotranspiration has approached pre-disturbance levels, the rate of carbon sequestration has not recovered yet. Overall, after several years this forest has still not recovered to pre-defoliation levels of canopy water use efficiencies and canopy carbon uptake.