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Non-linear response of ecosystem evapotranspiration to tree density: trees reduce water losses in constructed wetlands

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Climate change scenarios for the northern hemisphere predict not only an increase in temperature but also more frequent drought events. Both developments are known to stimulate shrub and tree encroachment in wetlands as a result of decreased summer water tables. It remains uncertain to what extent the changes in tree and shrub cover may speed up their own expansion by self-facilitation processes. It has been hypothesized that trees can make soil conditions drier by transpiration, increase soil nutrient availability by litter fall and reduce light by shading, thus improving their own growth relative to other species. We set out to test the effect of tree density on the water balance of constructed wetlands, expecting that evapotranspiration would increase with tree density.

We established a garden experiment in which 15 mesocosms (diameter 1.2 m, depth 1 m) filled with intact bog vegetation (Sphagnum mosses + Calluna vulgaris, Eriophorum vaginatum, Andromeda polifilia etc) were sunk into the middle of 10 x 10 m plots sown in with grass in April 2007. The mesocosms were subjected to three treatments (no tree, 1 birch tree or 2 birch trees) whereas the area surrounding the plots was planted with corresponding different densities of birch trees (no tree, 0.2 tree m-2 and 1 tree m-2). We followed changes in water balance terms, leaf area index (LAI) and vegetation composition between September 2007 & August 2010 and temperature at the soil surface for July 2009. Contrary to our predictions, mesocosms with the highest birch density lost significantly less water than the control mesocosms without birch trees. In contrast mesocosms with a low birch density behaved as expected and lost more water than the control without trees. Expressing evapotranspiration as a function of LAI revealed a non-linear relationship: evaporation relative to the control peaked at an LAI around 1 and became smaller than the control for an LAI of 1.7 and higher. Continuous temperature measurements at soil surface showed consistently lower mean and maximum values for the high birch density plots compared to the low birch density and open control plots, indicating a change in microclimate at high LAI.

We conclude that in the early phases of wetland colonisation trees make their environment drier. Once the canopy becomes denser however, this effect is increasingly offset by the changes in microclimate. As a result ecosystem water losses will decrease, and effects of shading and litter fall on the undergrowth will become more important. Our results show that density-dependant vegetation effects on the energy balance must be taken into account when estimating ecosystem water losses from wetlands.