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Xylem sap flow density along the radial profile is strongly reduced by repeated drought in mature spruce but not in beech

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The past decade with the drought years of 2015, 2018 and 2019 in Central Europe revealed strikingly the devastating consequences of severe and repeated drought/heat events on forest ecosystems. Nevertheless, responses of the water balance of trees and forest stands to such repeated drought events and subsequent recovery are poorly understood. The estimation of the water consumption of trees and forest ecosystems is a crucial part of many process-based models, especially under severe drought events. One major factor for the calculation of the water consumption per tree by xylem sap flow measurements is the radial profile of the xylem sap flow density decreasing towards the inner part of the sapwood. However such profiles are very scarce, especially under repeated and severe drought events.

Here, we present the changes of the profile of xylem sap flow density of European beech and Norway spruce within a five-year throughfall-exclusion (TE) experiment and a subsequent recovery. Two different methods were used to measure the xylem sap flow density up to 8cm sapwood depth, i.e. the heat dissipation and heat field deformation method. In beech, there was no difference in the linear radial profile between the TE and the CO (control) trees. However, under drought, for spruce the xylem sap flow density was strongly reduced along the profile by about 48 ± 16 % and the profile changed to an exponential decrease compared to the linear decrease for CO trees. Even two years upon drought release, the profile has not recovered. The reduction in the xylem sap flow density profile of drought stressed spruce was accompanied by heavy loss of fine roots and a reduction of the leaf area.

The use of standardized xylem sap flow profiles without the consideration of drought induced changes would lead to an overestimation of the water consumption of more than 30%. These results stress the importance of the radial profile measurements for the calculation of water balance of trees and thus forest ecosystems.