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Identification of soil properties affecting fine root distributions in forest soils

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Fine root distributions of forest stands express the ability of trees to exploit the soil matrix as their main source of water and nutrients. Soil physical and chemical properties act as conditioning factors and thus should influence the tree root intrinsic soil penetration strategies.
Within the German wide 2nd soil survey of forest soils, fine root distributions were measured in addition to soil chemical and physical measurements in the federal state of Baden-Württemberg at more than 300 sites representing the most characteristic geological, climatic and forest types. At each site, one soil profile was analysed with a 5x5 cm grid with fine roots <2mm being counted in each grid cell on a width of 20 cm and a depth of 100 cm. For statistical analyses, we used the empirical distribution functions (fine root distributions vs. soil depth) and derived the depths, up to which a certain percentage of roots (5-10-25-50-75-90-95%) was found. These percentiles were simplified using two principal components, one describing the degree of shallowness and the other describing the deviation of an idealized root distribution. Additionally, a cluster analysis was computed to detect distinct rooting types and factor and regression analyses were used to identify soil properties that can distinguish between the various root distribution types.
We found differences between coniferous and deciduous trees, with the deciduous trees tending to develop a deeper rooting system. Furthermore, on deeply developed soil types also the most deeply developed fine root distributions were found. In contrast, shallowest fine root distributions were found at weakly developed soil types or at soils with shallow bedrock or stagnic horizons. This indicates that distinct soil properties are responsible for the established root system at each given situation. Relatively high clay contents and bulk densities in the subsoil as well as high pH-values in the topsoil and low organic carbon contents in the subsoil influence positively the shallowness of the root distributions. High deviations of an idealized root distribution correlated positively with high bulk densities and high contents of gravel in the medium subsoil while higher contents of C and N in the deeper subsoil and relatively high pH-values in the humus layers were found at sites with more regular root distributions.
In summary, soil physical properties concerning the porosity and thus the resistivity to root penetration and chemical properties concerning the acidification and the organic carbon distribution seem to be the strongest factors describing differences in fine root distributions. However, it must be stated that all these correlations only explain a part of the differences between several rooting types, further research on other ecological factors is needed to obtain a more accurate understanding of fine root distributions in forest soils.