Water withdrawal in deep soil layers: a key strategy to cope with drought in tropical eucalypt plantations

Details

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Abstract

Little is known about the role of very deep roots to supply the water requirements of tropical forests. Clonal Eucalyptus plantations managed in short rotation on very deep Ferralsols are simple forest ecosystems (only 1 plant genotype growing on a relatively homogeneous soil) likely to provide an insight into tree water use strategies in tropical forests. Fine roots have been observed down to a depth of 6 m at age 1 year in Brazilian eucalypt plantations. However, the contribution of water stored in very deep soil layers to stand evapotranspiration over tree growth has been poorly quantified. An eco-physiological model, MAESPA, has been used to simulate half-hourly stand water balance over the first three years of growth in a clonal Eucalyptus grandis plantation in southern Brazil (Eucflux project, State of São Paulo). The water balance model in MAESPA is an equilibrium-type model between soil and leaf water potentials for individual trees aboveground, and at the stand scale belowground. The dynamics of the vertical fine root distribution have been taken into account empirically from linear interpolations between successive measurements. The simulations were compared to time series of soil water contents measured every meter down to 10m deep and to daily latent heat fluxes measured by eddy covariance. Simulations of volumetric soil water contents matched satisfactorily with measurements (RMSE = 0.01) over the three-year period. Good agreement was also observed between simulated and measured latent heat fluxes. In the rainy season, more than 75 % of tree transpiration was supplied by water withdrawn in the upper 1 m of soil, but water uptake progressed to deeper soil layers during dry periods, down to a depth of 6 m, 12 m and 15 m the first, second and third year after planting, respectively. During the second growing season, 15% of water was withdrawn below a depth of 6 m, and 5% below 10m. Most of the soil down to 12m deep was dried out the second year after planting and deep drainage was negligible after 2 years. As a consequence, during the third year after planting only 4% of water was taken up below 6m. However, during the dry season, this deep water still supplied 50% of water requirements. Our results show that deep fine roots of E. grandis play a major role in supplying tree water requirements during extended dry periods. Large amounts of water are stored in the whole soil profile after clear cutting and the fast exploration of deep soil layers by roots make it available for tree growth. After canopy closure, precipitation becomes the key limitation for the productivity of these plantations grown in deep sandy soils. Our results suggest that a territorial strategy leading to a fast exploration of very deep soil layers might provide a strong competitive advantage in regions prone to drought.

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