Complementary use of isotopic tracers and numerical model for analyzing root water uptake profile

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Competition for water among plant species coexisting within an ecosystem is an important phenomenon for properly understanding hydrological and ecosystem dynamics under changing climatic forcing. Isotopic tracer approach has enabled the characterization of differential water uptake among species, so there have been many reports on the water source separation from a wide range of ecosystems. However, it is still difficult to obtain reliable estimates of root water uptake profile (RWUP). The present study aims to establish a method to estimate RWUP by complementary use of isotopic tracers and numerical model. For this purpose, the newly developed method was applied to the two study sites: one is pure conifer plantation without inter-specific competition and another is mixed secondary forest, where competition occurs.

For both the non-competition and competition cases, numerical model based on measured root density profiles (RDPs) failed to reproduce xylem water isotopic composition (δ_{xw}). This error is probably due to inconsistency between measured RDPs and density profile of "active" roots. Adjusting RDP so as to simulate measured δ_{xw}, numerical model provided RWUPs almost identical to those estimated by isotopic tracer approach. Thus, the isotope-derived RWUPs are judged to be reliable from both chemical and physical aspects.

For the competition case, water-source separation was clearly found between co-occurring pine and oak trees; pine trees took up water from deeper depths and oak trees did from shallower depths. Sensitivity test with numerical model assuming different transpiration rate revealed that species having low transpiration rate cannot absorb water from dry, shallower soils and take up water from deeper depths. On the other hand, trees having higher transpiration can take up water from shallower soils, even though the soils are considerably dry. The reason for this is because high transpiration rate makes water potential within the plant body low enough to absorb shallow soil water. In either case, both species acted so as to minimize resistance against water transport through the soil-vegetation-atmosphere continuum. The hydraulic mechanism of water source separation mentioned above appears to be a passive response of plants to the occurrence of competitors. However, difference of measured RDP and adjusted (i.e., active) RDP indicates another aspect; pine trees might actively increase fine roots, which cannot be directly measured or quantified, in deeper depths. In this case, water source separation seems to be an active response of plants. Consequently, water source separation is concluded to be caused by a combination of active and passive responses of co-occurring plants.

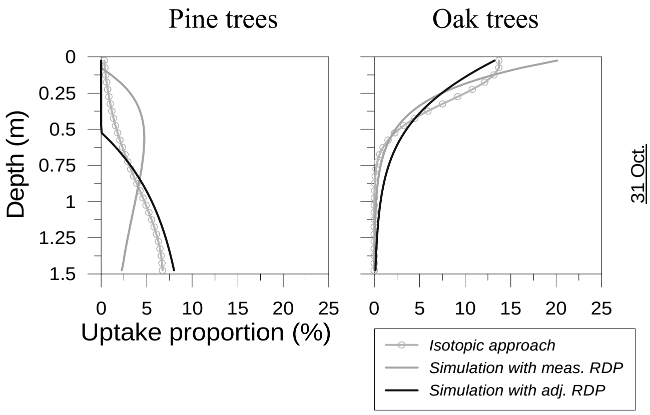

Fig. 1 RWUPs estimated by two independent methods.