USING STABLE ISOTOPES OF WATER TO TRACE PLANT WATER UPTAKE

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Abstract

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The stable isotopes of water (^2H, ^{18}O) are apparently not fractionated as plants take up water, as has been shown in laboratory and glasshouse studies. The authors verify this for a field situation in a semiarid area of southeast Australia in which *Eucalyptus* spp. are growing on a sand dune. No fractionation implies that the stable isotopes of water in the conducting tissue of plants can be considered to be the sum of stable isotopes from the various soil water reservoirs from which the plants may be extracting. If there are large enough natural variations in the isotopic composition of the soil and groundwater, the stable isotopes in the plant con-

1. INTRODUCTION

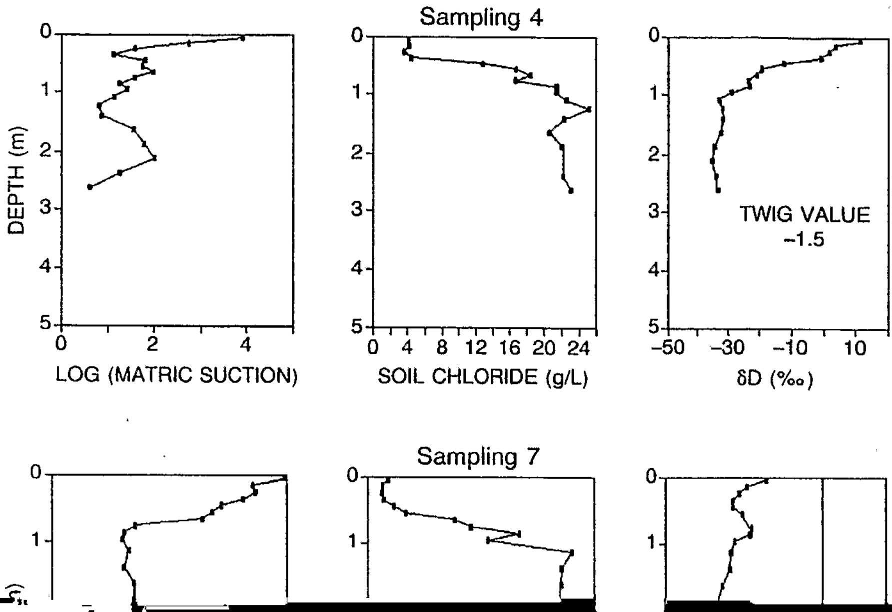
Long term drought and soil salinization are among the factors which contribute to a rapid extension of desertification in semiarid and arid regions of the world. In Australia, as in other dry countries, the natural vegetation is under stress owing to lack of water and/or excess salt. Because of the implications for natural vegetation, agriculture and water resources, it is important to have better information concerning the source of water for plants. Fresh water, essential for the survival of the vegetation, is usually present near the soil surface and in the groundwater. In this paper, we describe how stable isotopes of water (^2H, ^{18}O) can be used to find which reservoir of water the vegetation uses preferentially according to the environmental condi-

The geology of the region is described in Ref. [7]. Our site consists of a 7 m high dune adjacent to a saline discharge area. The aeolian dune overlies lacustrine clay of about 1 m thickness which in turn overlies the regional Pliocene sand aquifer. The regional groundwater is saline (TDS $\approx$ 40 $g \cdot L^{-1}$). A calcium carbonate layer exists at a depth of 1–3 m near the top of the dune. During the sampling period, there was evidence of perching above the clay layer. The dune is sparsely covered with

4. RESULTS

4.1. Intra-tree comparisons

For sapwood, there was no trend in ^{2}H values between the bottom of the trunk and the extremity of the twigs. The minima and maxima over the tree were −50 to −51 (HBD sampling 8 (12 October 1989)), −38 to −41 (HBD-9), −31 to −33 (2HTD-8) and −28 to −34 (2HTD-9). (All isotope values quoted are in ‰ relative to V-SMOW. The precision of the analyses is 2‰ for ^{2}H and 0.2‰ for ^{18}O.) These results are different from those in Ref. [4], in which a significant trend was found for the bean plant. There was in general no significant difference between heartwood and sapwood. The average values for heartwood and sapwood were, [illegible]


Sampling 4
DEPTH (m)
LOG (MATRIC SUCTION)
SOIL CHLORIDE (g/L)
δD (‰)
TWIG VALUE
−1.5
Sampling 7

0.5 to 1.75 m and high below this range. The δD values in the depth range 0.5–1.75 m vary from −48 to −38‰, with the twig values in exactly the same range.

The results of this comparison show that the isotopic composition of the soil layers with low to intermediate matric and osmotic suction is similar to that found in the twigs. For the three sampling times, the deuterium concentration in the twig varied from −48 to −1‰, but this was still consistent with the soil isotopic values.

4.3. Deuterium–Oxygen-18 plots

The ^{2}H–^{18}O plots for both soil and twigs for all sites at samplings 4, 6 and 8 are shown in Fig. 2. The best fit line to the soil data is also shown in Fig. 2. If the twig water is a mixture of soil water from various depths, it should lie close to the line approximating the soil data for ^{2}H–^{18}O. For sampling 4, all the twig data lie above the best fit soil line. For samplings 6 and 8, the twig data lie about the best fit soil line (lower layer). The reason for the difference in sampling 4 is probably due to the soil water being derived from recent rainfall and this lies above the general best fit soil line (closer to the meteoric water line). Relatively few of these samples would have been analysed for ^{18}O owing to the lack of water. Since, in general, there does not appear to be a bias in the twig samples relative to the soil data and the difference for sampling 4 is relatively small for the purpose of the isotope method, the investigation of this difference has not been pursued further.

A second feature of the ^{2}H–^{18}O plots is the position of the twig data relative to those of the surface soil and the groundwater. For sampling 4, the twig data are close to the surface soil values. The surface soil was relatively wet. For sampling 6, the twig data are close to the groundwater values. Sampling 6 is the driest of all the profiles shown (soil matric suction almost identical to that of sampling 7). Finally, there are two groups of twig data for sampling 8, one isotopically depleted, presumably corresponding to the heavy rainfall some months earlier, and another group

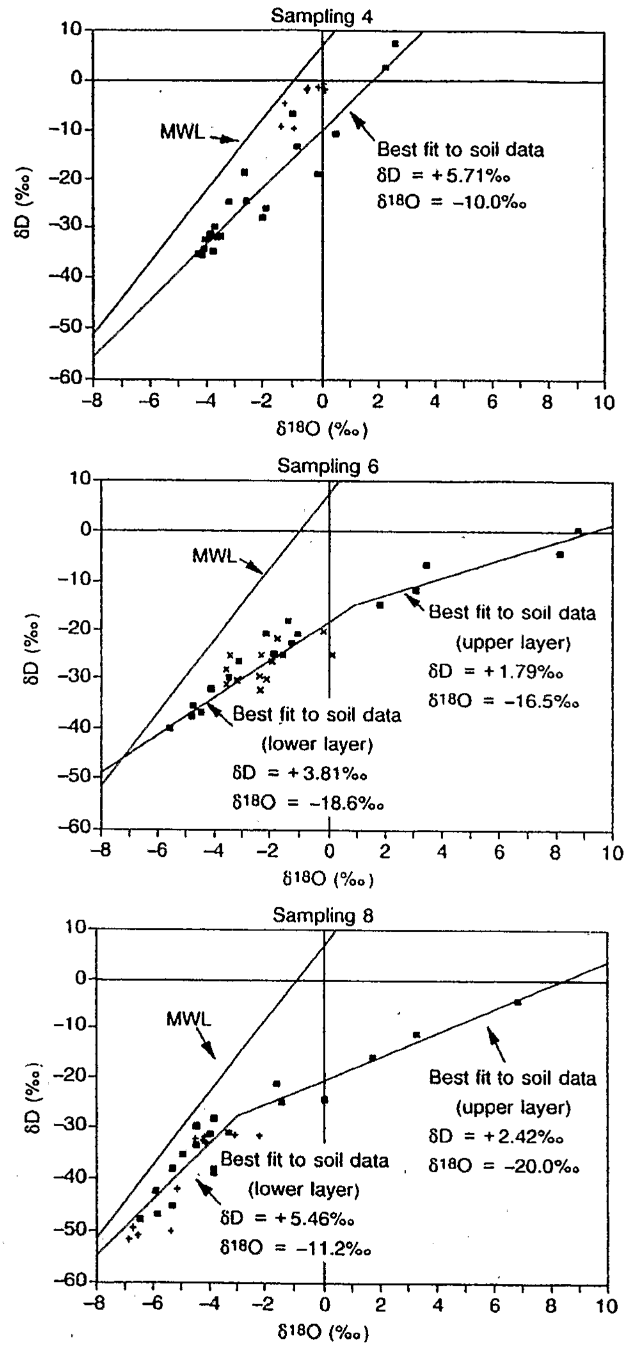


FIG. 2. ^2H–^{18}O plots for sampling times 4, 6 and 8. The local meteoric water line (MWL) and best fit line for the soil data are also shown. The soil data are represented by squares and the twig data by crosses.

time. This includes a range of soil moisture conditions of which some representative samplings have been described here. Over the study period, the twig isotope values varied by about 50‰ for deuterium and about 9‰ for ^{18}O. These very large ranges could be adequately explained by the soil matric suction, chloride and isotope data. If one makes the reasonable assumption that the plant will not take up water from soil for which the soil matric suction was very high and/or the soil salinity was high, one finds that the isotopic composition of the soil at the remaining depths is similar to that in the twig water. The fact that the twig data were consistent with the soil data for such a range of conditions and isotope values is the strongest evidence that the assumption of no fractionation in root uptake is valid under natural semiarid conditions for such vegetation.

There has been no attempt in this study to quantify the plant uptake or the soil water or isotope balance. However, it is possible with the present type of sampling to partition two different sources of water. Had the groundwater been fresh, as in the study described in Ref. [5], the water taken up by the plant would probably have been a mixture of the groundwater and soil water. For such circumstances, the $^{2}H-^{18}O$ plot could be used to define the relative contributions of soil water and groundwater.

In this type of study, the soil sampling is essential for partitioning water uptake. In some circumstances, the sampling of only rainfall, sapwater and groundwater (as in Ref. [5]) could be ambiguous. For example, in sampling 8 for the two higher sites, the isotopically depleted water from a previous rainfall event mixed with isotopically enriched soil water resulted in water of similar isotopic composition to groundwater. In the absence of soil isotope data, this may have been interpreted as the tree starting to use groundwater after the reserves of rainfall derived soil water had been depleted.

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