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Resolving the tree-water-stream water paradox in a humid, upland catchment

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The links between forests and streamflow are poorly understood, especially in humid, upland regions. Detailed process-based studies that explore the interface between plant physiological function and watershed flowpaths, flow sources, and residence times have not been widely attempted in humid forests. Recent stable isotope data from our work at Watershed 10 of the HJ Andrews Experimental Forest in western Oregon, USA has revealed that water used by the plants is not seen in the stream and the water seen in the stream is not the water used by the plants. Our new measurements in this humid, forested environment suggests that while diel transpiration rates are strongly coupled to diel streamflow patterns, the source waters for forest transpiration and for streamflow differ greatly in isotopic composition. At the end of the wet season, soil-water storage is at its maximum, and plant water uptake is primarily occurring from the surface soils where evaporative demand is high. As the dry season progresses, plants rely on water deeper in the soil. Evaporation leaves a distinct isotopic signature on the soil water. Our isotope data indicate that most water taken up by plants has been affected by evaporation prior to photosynthesis, including soil water deeper than 30 cm that is typically unaffected by evaporation directly. In contrast, stream water does not contain an evaporative isotopic signature even though discharge rates show distinct diel cycles driven by transpiration. This brings forward the concept of two separate pools of water held within the soil. One is a faster moving pool held at relatively weak matric potentials, making it more subject to gravitational transport to streams. The second pool is held more tightly by matric forces, has a longer residence time

within the soil, and will more likely to be taken up by plants. The implications of our data are that even when precipitation events are large enough to generate groundwater recharge following a long dry period, tightly bound water in the unsaturated zone is locally recycled by plants and remains poorly mixed within the subsurface.