Partitioning of the Water Balance at the Hillslope Scale: A Sprinkler Experiment at Watershed 10, H. J. Andrews LTER

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The water balance, or continuity equation, is the fundamental law in hydrology:

\[ P = LSS + OF + DS + \Delta S + ET \]

where \( P \) is precipitation, \( LSS \) is lateral subsurface flow, \( OF \) is overland flow, \( DS \) is deep seepage, \( \Delta S \) is change in soil moisture storage, and \( ET \) is evapotranspiration. \( OF \) is often assumed to be negligible, especially in steep, porous mountain soils such as at the HJA.

At the hillslope and catchment scale, closing the water balance has been difficult, and met with little success, due to uncertainties in inputs and difficulties in measuring outputs.

Sprinkler experiments are useful in investigating the water balance as inputs are controlled, and the limited uncertainties in the experiment makes monitoring of outputs easier.

During July and August, 2005, a sprinkler experiment was conducted at a trenched hillslope (8 X 20 m) in Watershed 10, H. J. Andrews, Oregon Cascades. Sprinkling was applied at a constant rate for 24.4 days while \( P, LSS, \Delta S \) and ET are measured. DS is estimated.

Steady state conditions, as determined by hillslope discharge and soil moisture, were reached in 8 days, and maintained for 12 days until sprinkler malfunctions increased \( P \).

Other goals of the sprinkler experiment were identification of nutrient and water flow paths in the soil and vegetation (see posters by van Verseveld et al and Barnard et al).

Water was supplied by the McKenzie River Forest Service Fire Crew to 6 1500 gallon tanks, transported to the site via 200m of fire hose and applied using 40 micro-sprinklers. A computer timer regulated sprinkling rate, and sprinkling rate was measured by an array of 72 cups amped 4X daily and 3 logging tipping buckets.

The mean annual precipitation (~2300mm) was applied to the instrumented hillslope in 24 days at 3.5 mm/hr. The spatial variability was not measured, but recording tipping bucket rain gauges indicated that the application rate was steady temporally except for 4 minor sprinkler malfunctions.

Evaporation and transpiration were relatively steady throughout the experiment, making up 5% and 1% of sprinkler application at steady state, respectively. Both were most sensitive to incoming net radiation, responding more to cloud cover than sprinkling.

Hillslope lateral subsurface flow was caused by trench sealed to bedrock at hillslope base. Water was routed to Y-Notched Weir with stage recorder for flow measurement. Manual measurements during and after experiment covered the range of observed flows to create stage-discharge relationship.

Soil moisture reached steady state value (likely not at saturation) after 6 days, and drained slowly after cessation of sprinkling. The deeper soil drained more slowly than surface. Steady state water content depended on both soil porosity and saturation.

The sprinkling was continuously monitored to ensure constant application, take samples and correct sprinkler malfunctions.

Evaporation was calculated using Penman-Monteith Equation with data from an on-site meteor station. Transpiration was measured with sapflow sensors on trees on the hillslope.

WS010 gauge station maintained by HJA staff and available online.

At the hillslope trench steady state conditions and strong soil pattern were seen after 6 days of sprinkling. Steady state discharge was 6 times background, and discharge quickly receded to background after sprinkling stops (~1 day). Peak after experiment end was due to logger error.

The streamflow recession at Watershed 10 was slower than at the hillslope, indicating longer flowpaths and increased storage. A storm 11 days after the experiment raised streamflow above the natural recession. The master recession for WS10 (inset) was created by comparing 3 previous years summer low flow and fit to an exponential model.

Water Mass Recovery

During the experiment, the hillslope trench caught 26% of sprinkled water. A large component: bypassed the trench, either percolating under or flowing laterally to the stream. This was measured at the WS10 outlet and made up over 40% of sprinkled water. While soil storage and evapotranspiration made up a significant portion of the water balance, between 11 and 24% of sprinkled water was left unaccounted for. We hypothesize that this water flowed in bedrock under the WS10 gauge, and was thus unmeasured. This "missing" water may need to be accounted for in water budgets for WS10 and other monitored watersheds in the HJA.

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