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Soil core experiment for a mixing process of rain and soil water using stable isotope

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Human activity has significant impact on water cycle and ecologic systems in river basins. In order to consider counter measures against those influences, we need to understand water cycle and its modeling that reflects appropriate hydrologic processes. To achieve right process modeling, we have been developing a method to calculate residence time and spatiotemporal sources of stream flow within a distributed rainfall-runoff model, so that we can compare the calculated values against field observations with stable isotopes. For calculating reasonable residence time and spatiotemporal sources within a model, it is essential to model reasonably the mixing processes of precipitation water and residual soil water.
Regarding rain and soil water mixing process studies at the catchment scale, Brooks et al. [2010] recently reported interesting field observation results with stable isotope. They measured isotopic compositions of rain water, soil water, vegetation water, and stream water to understand how stream water and vegetation water are originated. According to their findings, water used by plants in a dry season was totally different from that of flowing in streams in a rainy season. These observation results cannot be explained with the conventional concept of complete mixing of water within soil layers. Their explanation to this interesting finding was that at the beginning of rainy seasons rain water is stored in soil layer within tightly bounded area, whereas rainwater falling during a rainy season goes through the soil layer and feed to a stream directly.
Our study here is designed to validate this hypothesis through a soil column experiment. We prepared two sets of water showing different isotopic compositions and sprinkled them to the soil columns. We prepared two soil columns (F: 15.2 x L: 32.5 cm) from HJ Andrews Experimental Forest, then sprinkled to both of them with the first kind water (which we call wet up water). The total amount of sprinkled water was 100 mm within 5 hours. After waiting for 3 days to penetrate the wet up water, we opened one of the two columns and extracted soil water by cryogenic water extraction for isotopic analysis. Then we sprinkled the other column with the second kind water (which we call irrigation water, 200 mm during 5 hours) and measured isotopic compositions after 7 days of penetration. Our results showed that the isotopic composition of soil water after irrigation showed that the signals of first water despite the outflow showing almost identical signals of the irrigation water. In addition, the portion of wet up water and irrigation water in the soil column was nearly equal. These results indicated that soil water in the soil column did not mix completely even in 200 mm of precipitation. The experiment result supports the finding reported by Brooks et al. [2010]. Furthermore, it emphasizes the importance of appropriate soil water mixing process (not complete mixing) to calculate residence time and spatiotemporal sources of stream water within a distributed rainfall-runoff model.

Keywords: isotope, runoff process, immobile water, soil experiment, HJ Andrews