Variation of soil hydrophobicity and its effect on infiltration into forest soil

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Since 2001, soil moisture distribution has been monitored within a 50 cm × 50 cm transect on a forested hill-slope. The aim of the study was to assess temporal stability/variability of the infiltration process under natural conditions. Initial analysis of the data revealed changes of the infiltration pattern in the region close to the soil surface that appeared influenced not only by the initial moisture conditions but also by the history of wetting. It was hypothesized, that changes of soil hydrophobicity related to the temperature and soil moisture conditions may be a governing factor of the infiltration pattern changes observed. Therefore, in 2003 soil hydrophobicity measurements were conducted to gain information on the extent of that phenomenon.

1. Site characteristics

The site is located in Fudoji watershed in southern part of Shiga prefecture (experimental site of the Kyoto University Department of Forest Science). The slope is forested by Hinoki (Japanese cypress), Sugi (Japanese Cedar), and Konara (Oak). The monitored transect is situated on a hill-slope of about 35° slope, perpendicular to the slope, about 20 m from the top. The depth of the brown forest soil is approx. 75 cm. The samples for the hydrophobicity tests were taken within the same site.

2. Soil moisture monitoring

The transect was instrumented with 25 soil-moisture probes (CS615 Water Content Reflectometer, Campbell Scientific, Inc.) arranged in a 5×5 matrix with 10-cm separation distance. The probes are connected to a datalogger (CR10, Campbell Scientific, Inc.), and the readings are collected in 5-minute intervals. The probes were shortened to 10 cm to facilitate installation and thus the calibration provided by the manufacturer is not applicable. The available raw data reflect only qualitative moisture changes; for each probe, an increase or decrease of the output value signals an increase or decrease of the soil water content, respectively, however, interpreting the differences of read-out from different probes as a moisture-content difference may be misleading.

The overall results are illustrated in Figure 1, showing the time development of the soil moisture content between September 2001 and December 2003. It is apparent that the dry conditions of August and September 2002 were not repeated in summer 2003. As those dry conditions are thought to be a prerequisite of the soil hydrophobicity establishment, the data obtained in 2003 may be not fully representative of the soil properties possibly established during dryer years.

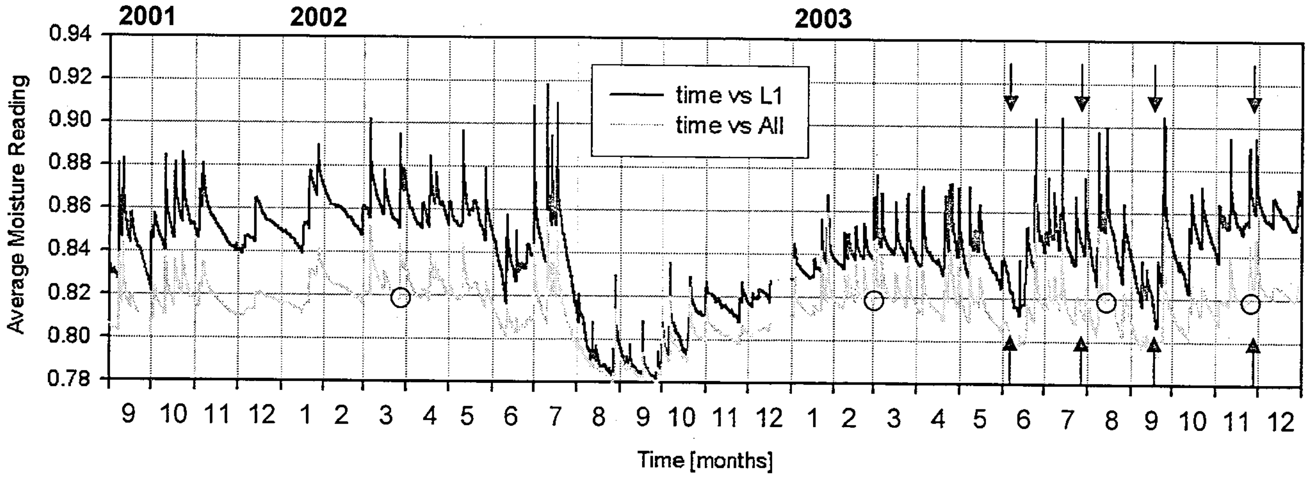

Figure 1. Time development of soil moisture content: average probe readings in the upper layer (10 cm below the surface) and in the whole profile (10 – 50 cm below the surface). The arrows mark sampling for the WDPT test, the circles mark the infiltration events presented in Figure 3.

3. Soil hydrophobicity measurement

The Water Drop Penetration Time test (WDPT) was used to asses the hydrophobicity of the soil. The test was applied to both naturally moist and air-dried soil, giving the actual and potential hydrophobicity, respectively. Soil samples were taken in three layers within the top 18 cm of the soil profile (5 samples in each layer). Testing was repeated four times during 2004 (as marked in Figure 1): in June (second layer only), July, September, and November. The results are summarized in Figure 2; the WDPT categories give the time sufficient for a water drop placed on the soil surface to infiltrate. Customarily, the 5-s category is classified as non-water repellent, the 60-s category as slightly water repellent, and the 600-s category as strongly water repellent.

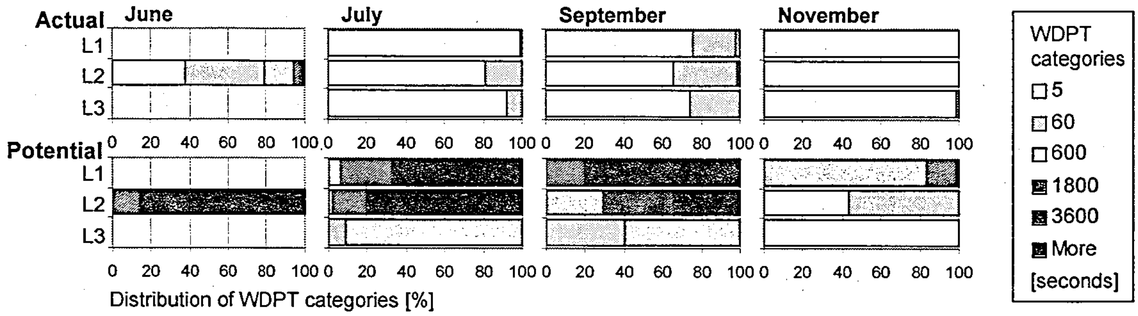

Figure 2. Soil hydrophobicity of moist (actual) and dry (potential) samples from three layers (L1, L2, and L3).

Except for the June measurement, the actual hydrophobicity was minor. The potential hydrophobicity of the surface layer (L1) showed an increase between July and September and a decrease afterward. In deeper layers, the potential hydrophobicity steadily weakened with time. It is possible that the observed hydrophobicity was established during the dry summer 2002, persisted to large extent till the spring 2003 and then gradually deteriorated throughout the year 2003, during which no severely dry season was observed.

4. Infiltration pattern development

Figure 3 presents the infiltration patterns observed at different times during rain-infiltration events the initial soil-moisture conditions of which were comparable (see Figure 1). The colour represents the increase of the moisture content relative to the initial conditions. The distinctly different pattern of March 2003 was typical for the after-dry period from September 2002 till March 2003; it was characterised by enhanced concentration of the flow in preferential pathways, bypassing portions of the soil layer near the surface. The initial moisture conditions in the top layer were dryer in March 2003 than a year before, however, instead of retaining more water the top layer seamed to resist wetting. This behaviour changed in March after which an infiltration pattern represented by the August and November examples was observed; it was characterized by more even wetting of the upper layer. Although slightly different patterns were observed as the initial moisture conditions and the rain intensities varied, no distinct change of the infiltration pattern character similar to that detected in summer 2002 was observed in 2003.

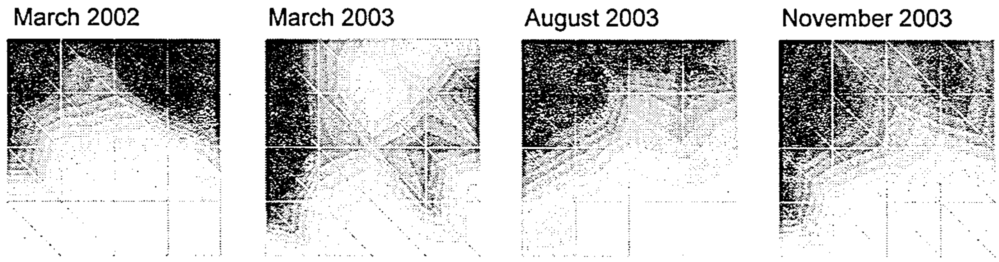

Figure 3. Infiltration patterns typical for different periods. The darker the hue the more the moisture increase.

5. Conclusions

Distinct infiltration pattern change was detected after dry summer 2002; that pattern, characterized by bypassing of the upper layer, persisted throughout the following half a year. Neither similar dry conditions nor the infiltration pattern change was observed in summer 2003. The soil hydrophobicity measurements, started in spring 2003, indicate gradual decrease of soil hydrophobicity. It is possible that the "bypass-flow-infiltration" pattern was related to the hydrophobic conditions in the upper soil layer, as soil hydrophobicity is known to be initiated by dry and hot conditions and it was detected in spring 2003. However, the data on soil hydrophobicity and water infiltration collected in 2003 do neither prove nor contradict this hypothesis.

6. Acknowledgement: Research is supported by JSPS scholarship P-02342