Hydraulic modeling of water flow in the thick vadose zone under precipitation

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Research

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Abstract

Since the visual observation of water flow in the vadose zone remains a challenge, two controversial theories have been proposed, namely non-uniform preferential flow and uniform unsaturated flow, also known as piston flow. This study used a hydraulic model to illustrate water flow in a vadose zone under intermittent recharge by precipitation. The model comprises a set of vertically aligned water tanks. A small outlet is set in the bottom of each tank through which water can flow out. This study conducted a physical experiment and derived the theoretical solution to investigate variations in tank water under intermittent water recharge. Water was supplied to the top-most tank to simulate precipitation. The water levels of the upper tanks varied over time whereas water levels in the lower tanks stabilized. The variable water levels of the upper tanks were attributed to the intermittent water recharge boundary condition and water flow into and out of these tanks represented transient flow. The stabilization of water levels in the lower tanks reflected mean recharge of the boundary condition. The measured rainfall series of a site in Gansu province, China was taken as the boundary recharge to simulate using the model. The same scenarios were also produced and confirmed by *in-situ* monitoring data. The results clearly showed that although water content in the lower vadose zone did not change, steady flow supplied groundwater. Therefore, uniform unsaturated flow (piston flow) is the main water flow process occurring in the thick vadose zone.

Full Text

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Figures

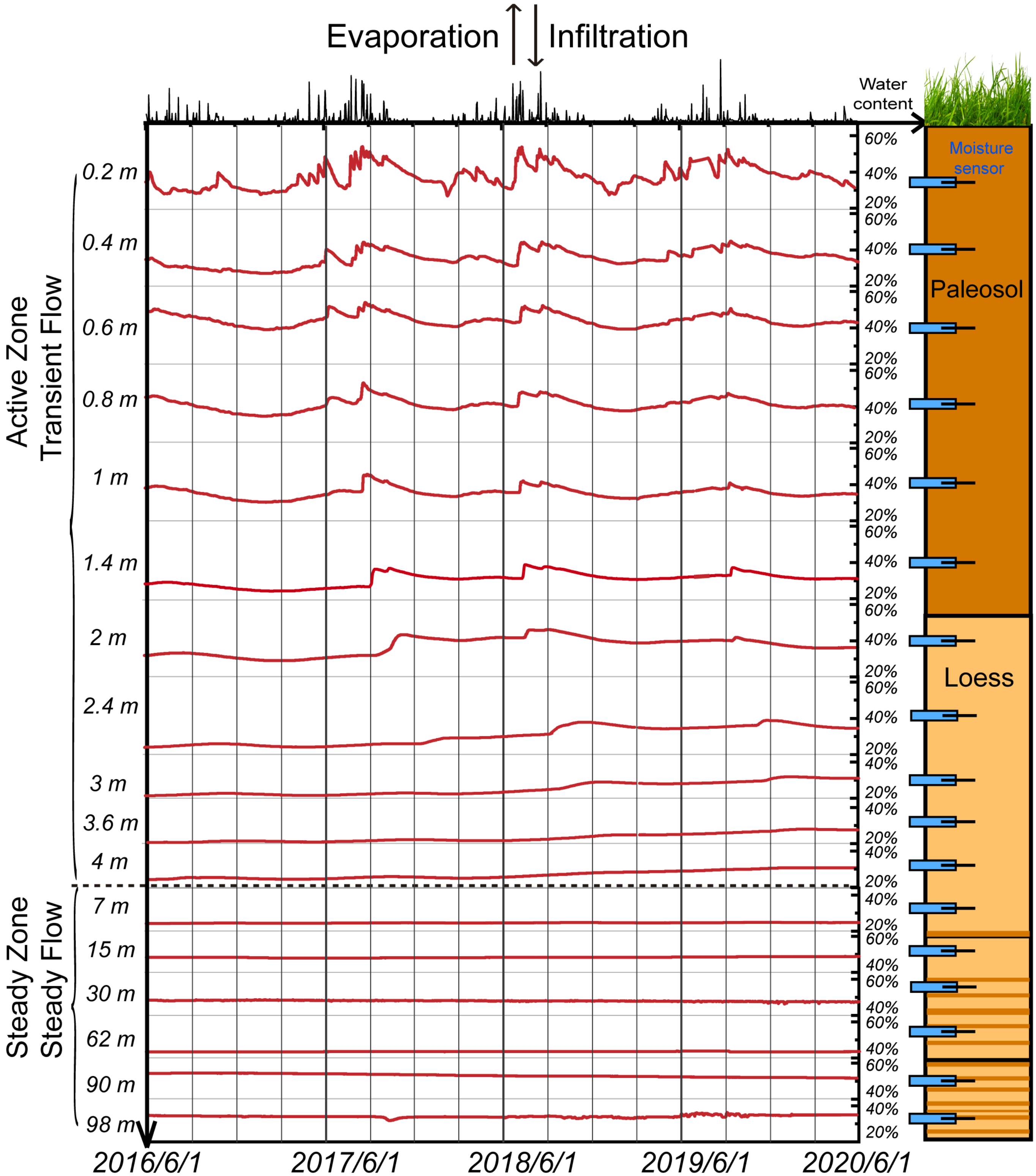

Figure 1

The results suggested that the depth at which soil moisture was most sensitive to rainfall and evaporation-transpiration is only 2 m, whereas water content below 2 m remains constant. Fig. 1 shows the results of up-to-date data.

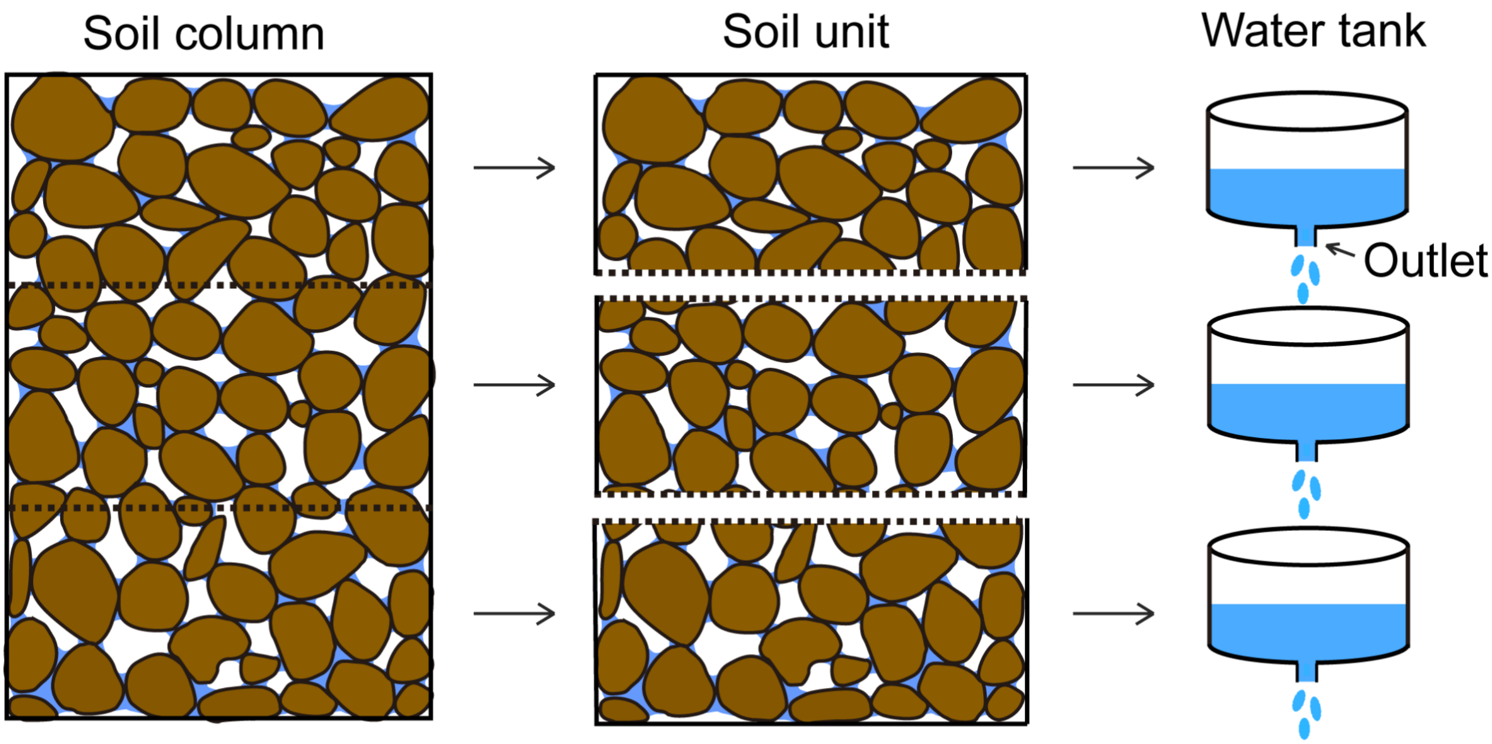

Figure 2

Fig. 2 is a schematic of the hydraulic model.

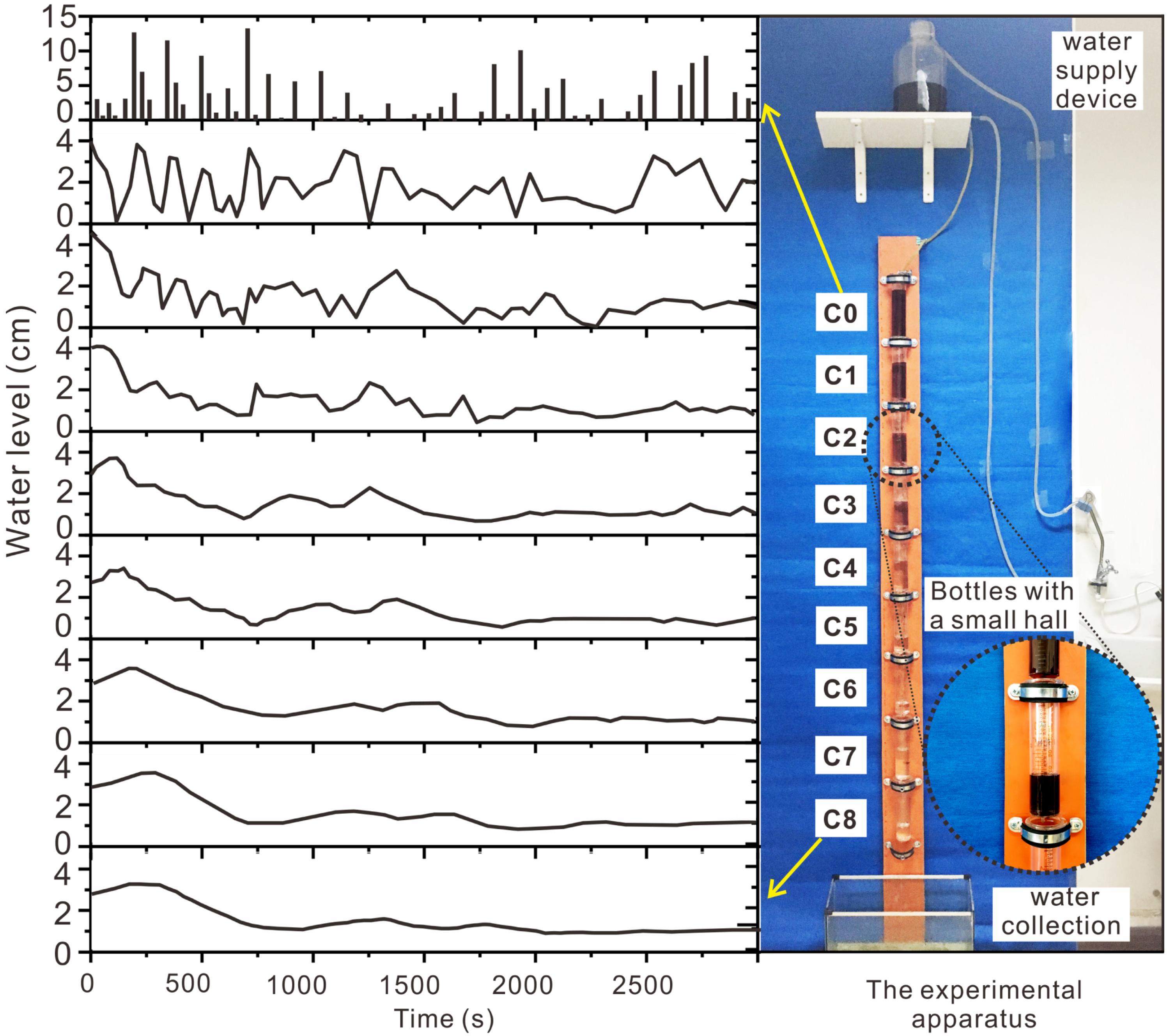

Figure 3

The boundary condition of the physical experiment was an intermittent water supply to the top tank C0 for simulating rainfall events, as shown in the first row in Fig. 3. The left-hand side of Fig. 3 shows the water level versus time, where it is evident that water level in C1 showed a constant wide fluctuation, which was evidently influenced by water supply in C0.

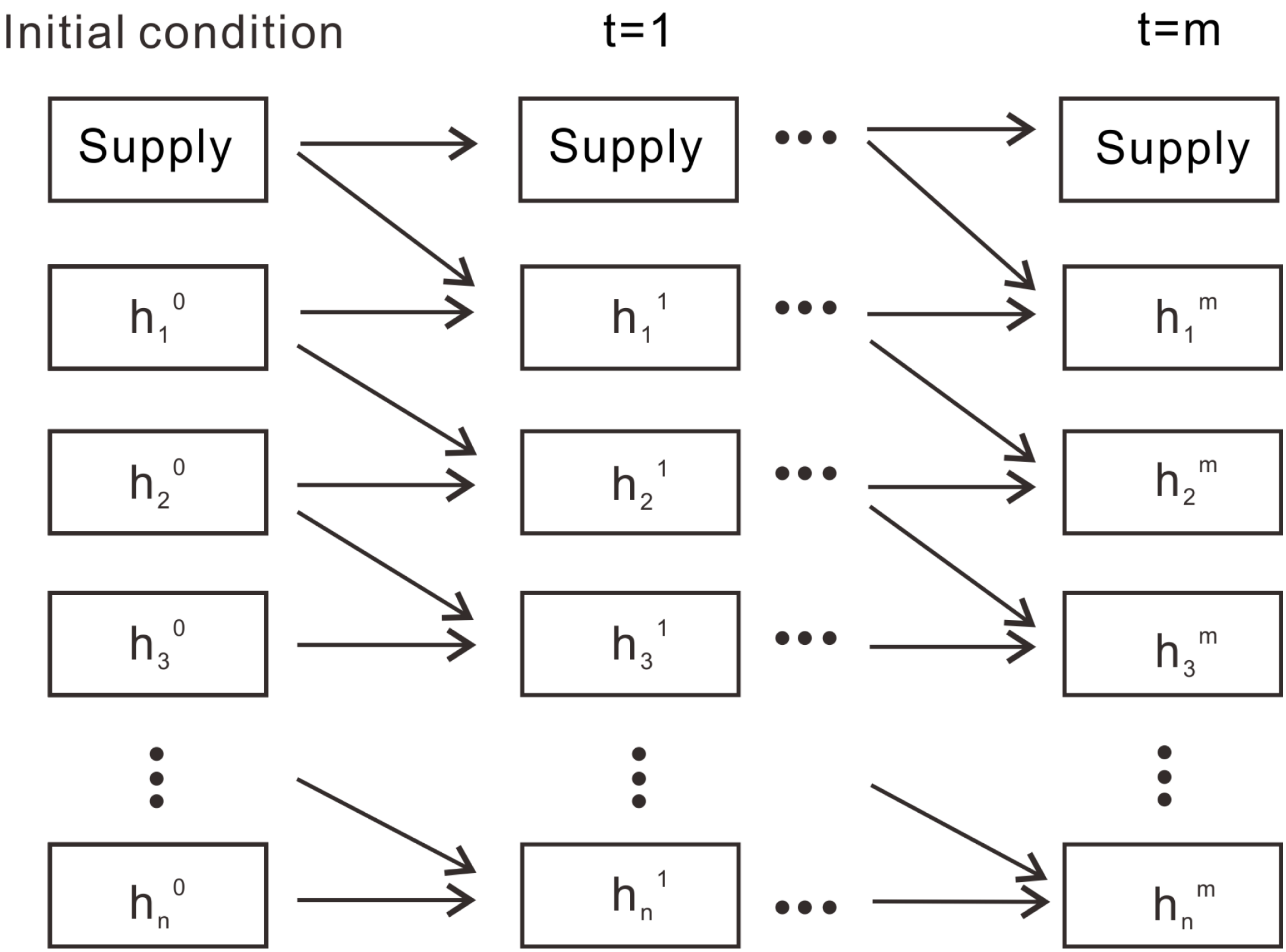

Figure 4

Fig. 4 demonstrates the calculation process.

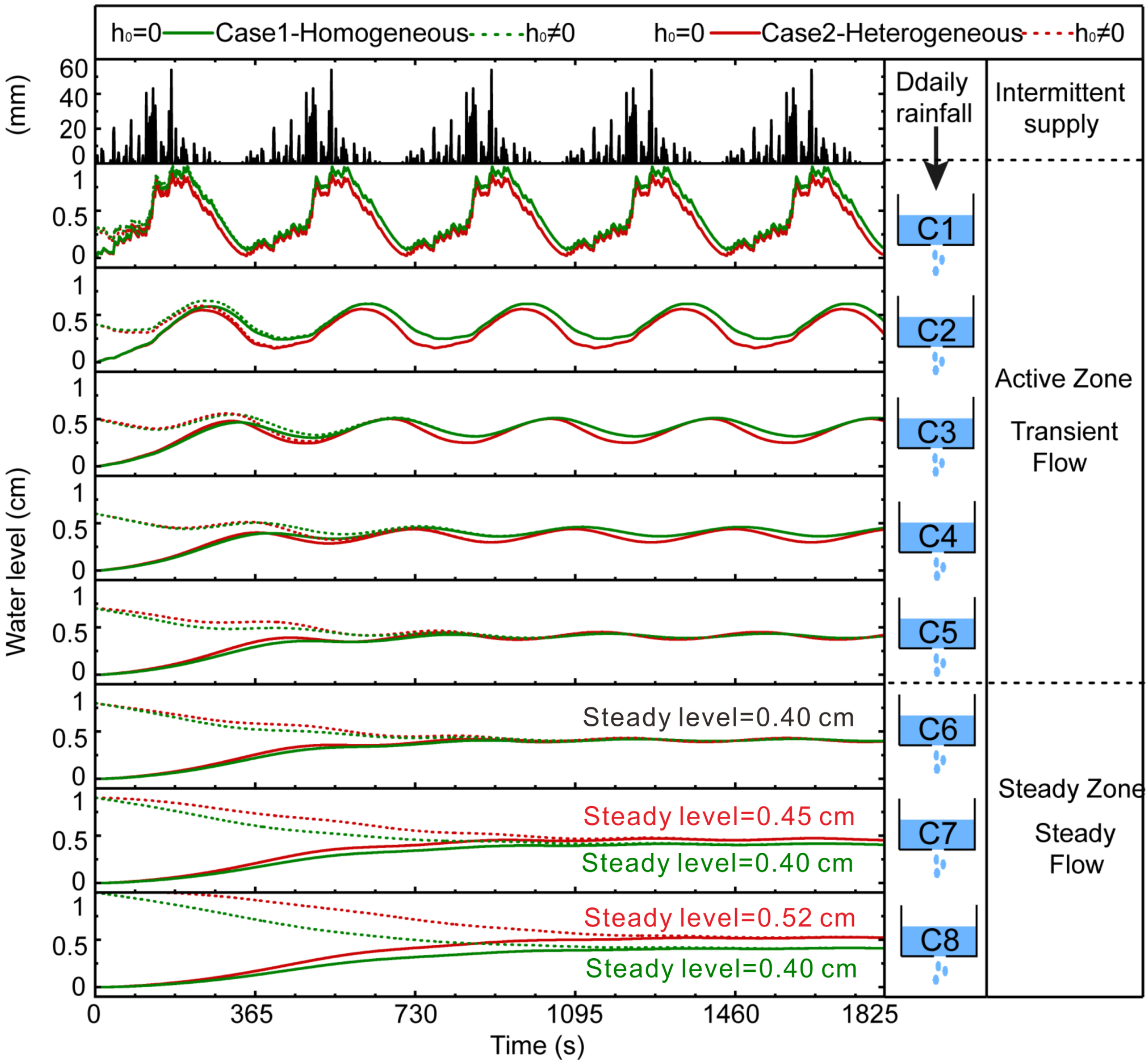

Figure 5

Fig. 5 shows all calculated results.

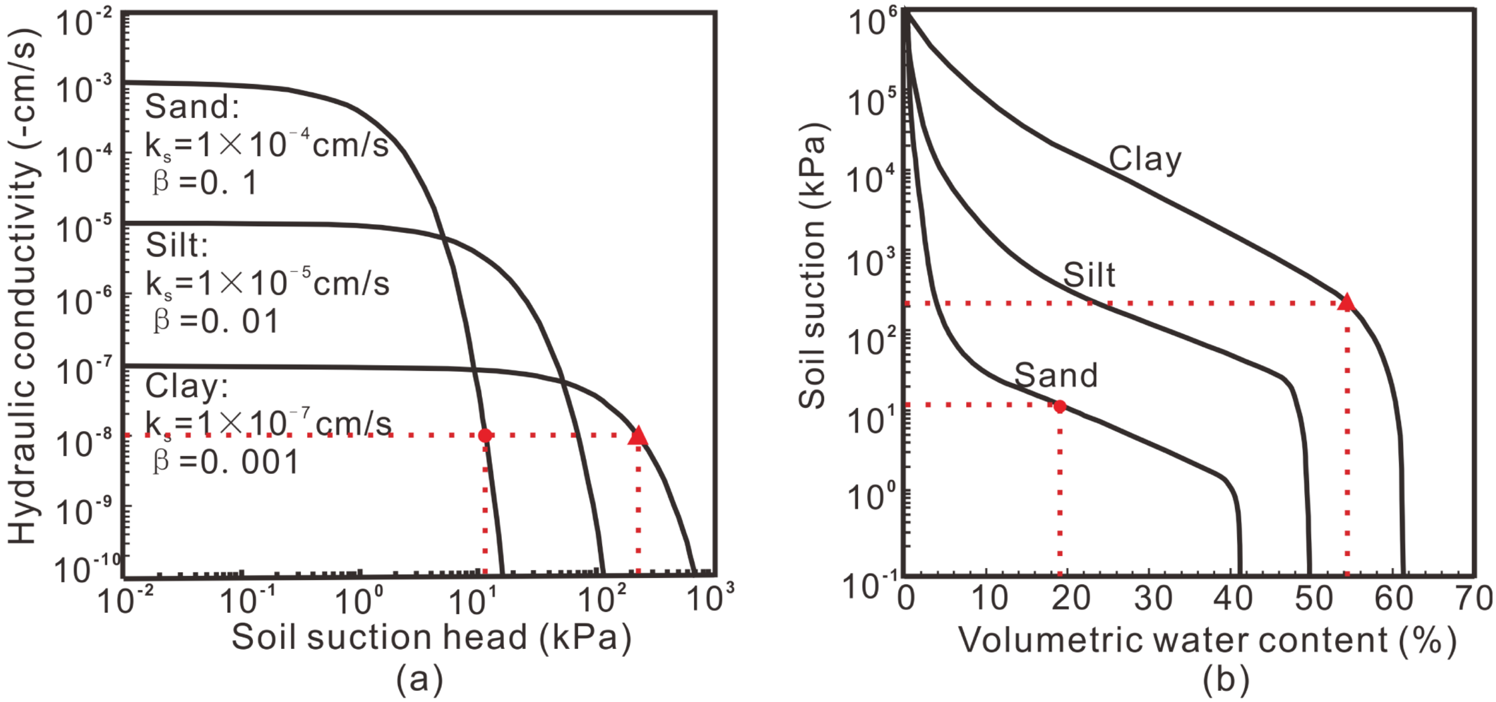

Figure 6

Fig. 6 shows the typical hydraulic conductivity functions for sand and clay.

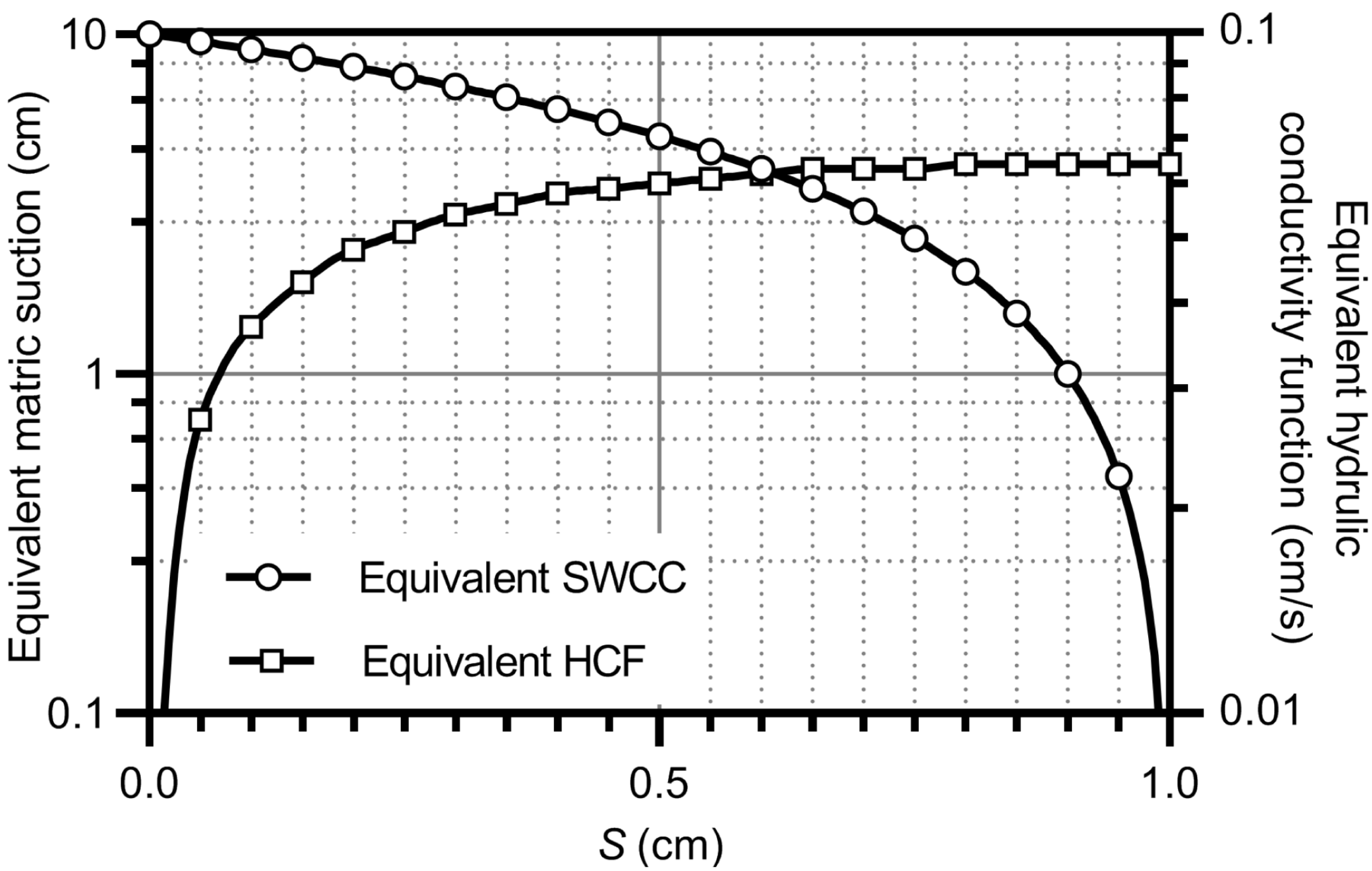

Figure 7

Fig. 7 shows the curves of Eq. (9) and Eq. (10). Eq. (9) is a linear function in which the equivalent matric suction linearly increases with decreasing saturation, similar to the trend in SWCC variation for real soil.