Supplementary material

S1 Vadose-zone monitoring system (VMS)

The need for real-time information on the quality of percolating water in the unsaturated zone led to the development of a VMS. The VMS is designed to provide continuous in-situ measurements of the hydraulic and chemical properties of the entire vadose zone, from land surface to the water table (Dahan et al., 2009). The monitoring system is composed of a flexible sleeve made of thin urethane liner, hosting several customized flexible time-domain reflectometer (FTDR) probes for water-content tracking (Dahan et al., 2008; Rimon et al., 2007), and vadose zone sampling ports (VSPs) for sediment porewater sampling (Dahan et al., 2014; Rimon et al., 2011; Turkeltaub et al., 2016) (Fig. S1).

Accordingly, information obtained by the VMS is used for direct measurements of flow velocities, solute transport and chemical transformation of the percolating water, from land surface to the water table (Turkeltaub et al., 2015a, 2015a). To date, the system has been successfully implemented in several studies on water flow and contaminant transport under various hydrogeological conditions including: (a) rainwater infiltration and groundwater recharge (Rimon et al., 2007; Turkeltaub et al., 2015a), (b) floodwater infiltration in arid lands (Amiaz et al., 2011; Dahan et al., 2008), and (c) agricultural impact on groundwater quality (Baram et al., 2012; Dahan et al., 2014; Turkeltaub et al., 2015b, 2016). In addition, transient data on the temporal variations in vadose zone water content and chemical composition of the sediment pore water enable calibration and validation of flow and transport models to the actual dynamic characteristics of the vadose zone (Turkeltaub et al., 2014, 2015a, 2015b).

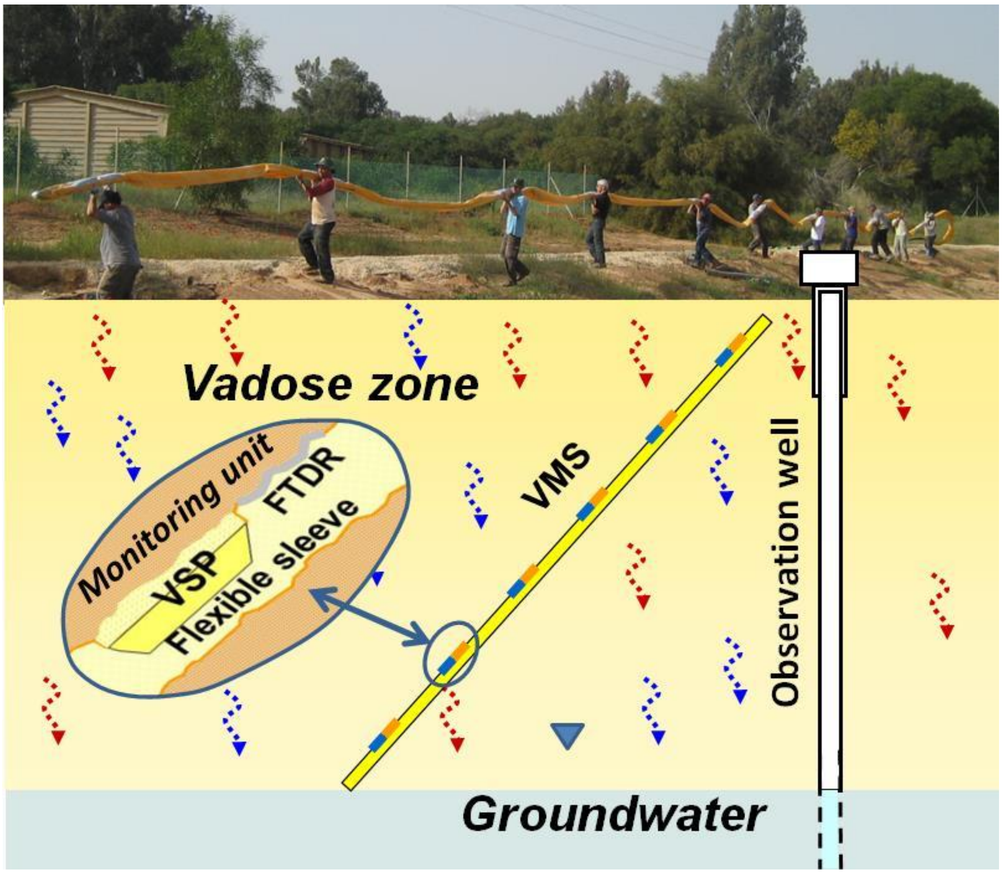

Figure S1. *Schematic illustration of a vadose zone monitoring system (VMS) with its monitoring units and a photo of a VMS carried on for installation.*

S1.1 Installation

The monitoring systems are installed in uncased, small-diameter (~0.15 m), slanted boreholes (55° to the horizon). The FTDR probes and VSPs are aligned along the borehole's upper side wall facing the undisturbed sediment column, which extends from the probe location on the borehole wall to land surface. Immediately after inserting the sleeve into the borehole, it is filled with non-shrinking cement grout. The hydrostatic pressure generated by the filling material within the sleeve causes its expansion and ensures that it fills the entire void of the borehole. As a result, the FTDR probes and VSPs are pushed against the borehole’s upper side wall with sufficient force to achieve good contact with the sediment. The combination of flexible sleeve with high-density filling material ensures tight sealing of the borehole void and elimination of potential preferential flow and cross-contamination along the sleeve.

S1.2 FTDR

The FTDR probes are designed to provide information on the infiltrating water via temporal variations in the vadose zone water content. The FTDR probes are made of flexible waveguides attached to a flexible sleeve. Filling the sleeve with the cement grout causes its expansion and attachment of the flexible waveguides to borehole walls. The flexibility of the waveguides enables full contact despite the roughness, undulations, and diameter irregularities of the uncased borehole. The inner side of FTDR waveguides are shielded with 3cm thick dielectric insolation to prevent potential impact of the cement on water-content measurements. The FTDR operates with Campbell Scientific data-acquisition and logging instruments, including TDR100, SDM50X and AM16/32 multiplexers, and CR10X data loggers. All waveguides are connected to the acquisition system using a high-quality RG-58 coaxial cable (shielding factor >95%). Due to the known effect of cable length on TDR waveforms, a linear relationship between apparent (La) and real (L) cable length is implemented and the cable length correction is established (Rimon et al., 2007): Corrected La/L = measured La/L - cable L × 0.016. Finally, a calibration curve for volumetric water-content measurements by FTDR probes was established for several different soils (Rimon et al., 2007). The calibration showed a linear correlation between the TDR signals (the calculated apparent length divided by the real length) and the volumetric water content (Fig. S2). The FTDR is a patented technology (Flexible probe for measuring moisture content in soil, US Patent # 6,956,381).

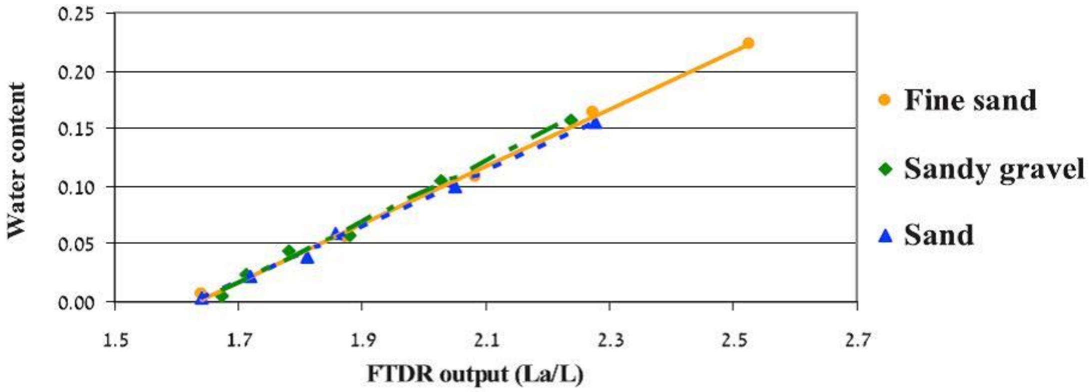

Figure S2. *Calibration curve for water-content measurements by FTDR probes for three different soils. FTDR output presented as apparent length/actual length (Rimon et al., 2007).*

S1.3 VSP

The VSP enables frequent sampling of the vadose zone pore water. The physical mechanism underlying the sampling is based on creating hydraulic continuity between the sediment pore water and the sampling cell, similar to a standard tensiometer or suction cups. Hydraulic continuity between the VSP and the rough sediments on the borehole sidewall is achieved through an unconsolidated agent made of flexible quartz powder. The VSP is operated through a set of small-diameter access pipes (i.d. (<1 mm) reaching a control panel on the surface. Once hydraulic continuity between the sediment pore water and the VSP is achieved, low pressure (vacuum) is applied to the sampling cell to draw the sediment pore water into the sampling cell. The water sample is then retrieved to land surface using pressurized gas (N_2). Finally, the sampling efficiency, as expressed by the water flux into the sampling cell, is controlled by the sediment water content. The VSP is a patented technology (Deep vadose zone sampling ports, US #12/222,069; EP #07706061.4; IL #193126).

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