Effect of soil type on estimating infiltration front depth using time-lapse array antenna GPR data: A numerical study

*Koki Oikawa[1], Seiichiro Kuroda[2], Hirotaka Saito[1]

1. Tokyo University of Agriculture and Technology, 2. NARO Institute for Rural Engineering

As an array antenna ground penetrating radar (GPR) system electrically switches any antenna combinations sequentially in milliseconds, multi-offset gather data, such as common mid-point (CMP) data, can be acquired almost seamlessly. The array antenna GPR system has been used to track the infiltration front and estimate its depth during the field infiltration experiment (*Iwasaki et al.*, 2016) by collecting time-lapse CMP data. Electromagnetic (EM) wave velocities were then obtained to estimate the infiltration front depths. Our previous study showed that the GPR estimated infiltration front depths agreed reasonably well with independently measured infiltration front depths. It is however still not well understood where the EM wave was actually reflected at the infiltration front because the soil water content changes gradually from the transmission zone toward the infiltration front. This shape depends upon the soil type. Because of recent technological advancement, there are a number of simulation tools available for both water flow and EM wave propagation in soils.

The main objective of this study was to investigate numerically the effect of the soil type on estimating the infiltration front depth using array antenna GPR data. While HYDRUS (2D/3D) (*Simunek et al.*, 2018) was used for simulating water flow in variably-saturated soils, gprMax (*Warren*, 2016) was used to simulate propagation of pulse EM wave in such soils by assigning dielectric constant and electrical conductivity correspond to simulated soil water content within the simulation domain. Sandy loam and silt loam, hydraulic properties of which were obtained from the database of HYDRUS (2D/3D), were compared in this study. The simulation time was set to 6 hours for sandy loam and to 40 hours for silt loam so that the position of the infiltration front reached at around 1 m deep. EM wave propagation was simulated at a given elapsed time to obtain CMP data. Then, the HYDRUS simulated infiltration front depth and the GPR obtained infiltration front depth were compared.

Results showed that GPR estimated reflection point was shallower than the simulated infiltration front for silt loam due to the gradual change in the volumetric water content near the infiltration front compared to sandy loam. The dielectric constant estimated from the EM wave velocity was then used to compute the average volumetric water content of the transmission zone to compute cumulative infiltration. When the infiltration progressed sufficiently long enough, the flux was assumed to asymptotic to the hydraulic conductivity. Based on the computed cumulative infiltration, the hydraulic conductivity was estimated. As a result, the accuracy of sandy loam was higher than that of silt loam.

References

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