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Assessment of Spatial Distribution of Surface Moisture Content of Kanto Loam using Ground Penetrating Radar

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Moisture content of surface soil is a key hydrological parameter in many disciplines such as agriculture, engineering, and hydrological practices. In general, it is highly variable in space and time and difficult to characterize using conventional methods. Surface ground penetrating radar (GPR) has shown promise to estimate the surface moisture content in noninvasive manner with good accuracy at large scales. The ground wave (GW) of surface GPR is used for moisture measurement of shallow surface soil. To date, this approach is limited only coarse textured soils but has not been practiced much for loam, clay, and organic matter rich soils. The specific aim of the present research was thus to characterize the potential of GW applications for mapping of surface soil moisture content of Kanto loam. Kanto loam (andisol) is a well structured volcanic ash soil (sand: 50%, silt: 44%, and clay: 6%) with high organic matter. Unlike other non-structured loamy soil, this soil has small bulk density (0.6 ~ 0.7 g cm[sup]-3[/sup])), in other words, very large porosity (0.7-0.8). It has not been deeply investigated whether or not GPR is suitable to estimate soil electrical and hydraulic properties of this type of soil.
The experiment was conducted on one of the Kanto loam sites of Field Science Centre of Tokyo University of Agriculture and Technology. An area of 40 m [sup]2[/sup], divided in 10 equidistant parallel lines were used for GPR measurements. Along the boundary of x-axis soil moisture sensors of three different lengths (5, 10, and 20 cm) were vertically installed for reference measurement of moisture content. A pulseEKKO PRO surface GPR system developed by Sensor & Software, Co., having 250 MHz central frequency was used for measurements. The common-offset survey mode of GPR was used for moisture content analysis. The GW travel time was used to estimate velocity (i.e. v [sub]gw[/sub] = antenna separation/ GW travel time), and dielectric constant (K = (c/vgw) [sup]2[/sup]), where c is velocity of light in vacuum (3 x 10[sup]8[/sup] ms[sup]-1[/sup]). Finally Toppempirical relation was used to estimate the moisture content. Moisture content based on GW analysis showed good correlation with EC5 than EC10 and EC20 based moisture content values. This indicates that the GW sampling depth at this site was less than 10 cm. Depth analyses using existing analytical models proposed by Sperl (1999) and Pallavi (2009) were found in good agreement with experimental results than other models. The similarity between GPR and EC5 showed the significance that GPR is providing spatially dense and potentially valuable information about the surface moisture content variations in non-invasive and rapid manner. Finally, spatial map of moisture content was obtained by combining GW based values of all 10 lines. The site showed large variations (e.g. 0.3 to 0.45 m[sup]3[/sup]m[sup]-3[/sup]) in the moisture content values. Potential causes of this spatial variability should be concerned with soil hydraulic properties, soil texture and/or topography of the site. From this study, Kanto loam is verified as a good site for GPR applications.

Keywords: Ground penetrating radar, Moisture content, Ground wave, Kanto loam