Estimating of infiltration path using 3D simulation of groundwater flow and resistivity survey

*Keisuke Inoue[1], Hiroomi Nakazato [1], Tomijiro Kubota[1], Koji Furue[2], Hiroshi Yoshisako[1], Michiaki Konno[1], Daisuke Shoda[1]

1.National Agriculture and Food Research Organization, 2.Kagoshima Prefectural Institute for Agricultural Development

Resistivity survey is a useful method for noninvasively imaging continuous water flow in soil because water saturation increases electrical conductivity. Several methods have been applied to determine the water flow in soil by monitoring the resistivity change that is associated with variation in water saturation or water salinity. A change in resistivity before and after infiltration provides a 3-D image of the water flow; however, a detail distribution of resistivity sometimes cannot be obtained because of the inherent limitation of the observation data (i.e., number of measurements, time represented, and measuring sensitivity). However, a resistivity change is caused by the water flow in soil, and the water flow is governed by the seepage phenomenon; therefore, a method that uses data from resistivity surveys and seepage analyses would be effective. Thus, a water flow model was developed, which compared the water content converted from resistivity survey data as well as water content simulated from hydraulic models. This method provide both an image of the water flow and the properties of the hydraulic conductivity; however, if the number of measurements is low, the resistivity obtained from inversion remains uncertain because of spatially varying resolution. Comparing water content values obtained from resistivity surveys with those from water flow simulations includes a 3-D inversion uncertainty. However, according to the coupled approach, the observed resistivity data are directly used for determining the hydrological properties. In this method, water content simulated from water flow analysis is converted to a resistivity model, and a resistivity survey is conducted using this model to interpret the results. The simulated resistivity data are compared with the field observations to estimate the water flow hydraulic properties. This method can reduce the spatial uncertainty of the 3-D invasion because the resistivity model is constrained by the seepage analysis data. One dimensional hydraulic properties were inverted from 1-D water flow simulations, whereas, using 2-D hydraulic properties were inverted via Bayesian and multi-criteria inversion and via neural networks. However, few studies investigated 3-D hydraulic properties using 3-D water flow simulation and 3-D resistivity survey data. Inversion of 3-D hydraulic properties is best but it is difficult because reconstructing the 3-D conditions is complex, and there are many unknown parameters. In this study, we propose an easy the method to estimate hydraulic properties of the shallow soil layer, which is responsible for many hydraulic problems in the field. To evaluate this method, numerical and field experiments ware conducted. In the numerical experiment, the resistivity survey provides an image of the preferential flow; however, the infiltration locations are unclear. Assuming that high hydraulic conductivity zones exist somewhere, an analysis of saturated-unsaturated seepage is conducted for several water-flow models with different locations of high hydraulic conductivity. Subsequently, a resistivity survey is implemented based on the water content that was simulated by seepage analysis. The high hydraulic conductivity location of the model that provides the minimum errors corresponds to the high hydraulic conductivity location of the numerical field model. In the field, resistivity is measured during groundwater recharge experiment in a pyroclastic plateau. This resistivity survey provides an image of the preferential flow; moreover the high hydraulic conductivity location of the model that provide the minimum errors corresponds to filling water rage, whereas that of the model that gives the maximum errors

corresponds to no filling water range. These results indicate that estimating high hydraulic conductivity locations using simulations of the groundwater flow and resistivity survey is possible. This work was supported by JSPS KAKENHI Grant Number 25850170.

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