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The thermal conductivity dependence on texture and dynamic measures of porous media

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Introduction

The thermal conductivity is an important factor influencing the surface-energy partitioning and energy flux in porous media. Direct measurements of the conductivity are still difficult and expensive. For this reason the methods for determination of the soil thermal conductivity based on easily measured or available in databases measures are suggested. In respect to soil medium the statistical-physical model based on terms of heat resistance (Ohm's law and Fourier's law), two laws of Kirchhoff and polynomial distribution was proposed. In this paper we present advantages and drawbacks of the model application to determine the thermal conductivity in various porous media.

Results and discussion

The model was verified in variously textured mineral and organic soils and intensively trafficked vineyard and agricultural soils with a relatively wide range of static and dynamic measures. The model performed satisfactory the thermal conductivity of sand, loam, silt, clay, peat and peat-sand mixtures from various sites in comparison with data measured using stationary and non-stationary method (a thermal probe). Regression coefficients and intercepts of the linear regression were respectively close to 1 and 0. The determination coefficients R^2 varied from 0.948 to 0.994, root mean square errors (RMSE) – from 0.057 to 0.123 W $m^{-1}K^{-1}$, and maximum relative errors – from 12 to 38.3%.

In the interrow vineyard soil under grass cover and bare fallow the thermal conductivity was interactively influenced by variously distributed soil water content and soil compactness along the slope. The distribution pattern of the thermal conductivity was very similar with that of soil water content. The effect of bulk density on the conductivity was less pronounced.

Since the thermal conductivity and penetrometer resistance are mostly influenced by water content and bulk density, attempts are undertaken to predict the thermal conductivity based on the resistance being more easily measured. The research under controlled space conditions indicates a positive relationship between the penetrometer resistance and thermal conductivity. However, these parameters were not much related, when we used the data measured in the soils under field conditions. This can be due to variability of soil water content, bulk density as well as texture (or mineralogy) and associated their spatially different influential intensity. The use of the recently developed penetrometers equipped with TDR probe for measuring soil water content within the same volume can improve the relationship by minimising complication due to soil heterogeneity. Further improvement could be possible by employing a thermal sensor. Additional benefit of the integrated systems is expected in fewer disturbances of the porous media under tests.

Overall, the results indicate that the statistical-physical model predicts well the thermal conductivity. Under the heterogeneous media, the use of integrated systems for simultaneous measuring strength, moisture and heat, exhibiting high spatial variability, can be helpful to identify most influential variables affecting the thermal conductivity under various compactness and wetness of porous media.