The thermal conductivity is influenced by variable soil water content, bulk density, temperature and by relatively stable mineralogical composition and organic matter content. Recognizing the spatial and temporal variability of texture and wetness based on a large number of soil experiments and their effect on the thermal conductivity may be helpful for estimating and control of soil heat flux. This paper presents results of soil texture, wetness and bulk density that were measured in two networks in surface layer (1-10 cm), near Lublin, Poland. The measured values were employed to assess thermal conductivity of soil by means of the physical-statistical model by B. Usowicz.

### Physical-statistical model of thermal conductivity

The physical-statistical model is based on terms of heat resistance (Ohm’s law and Fourier’s law), two laws of Kirchhoff and polynomial distribution. Soil thermal conductivity $\lambda$ (W m$^{-1}$ K$^{-1}$) was calculated by the following equations (Usowicz 1992, 1995, 2004):

$$\lambda = \frac{P_{ij} \cdot f(x_i, x_j)}{V_{ij} \cdot f(x_i, x_j)}$$

where $\lambda$ is the number of all combinations of particle configuration possible, $x_i, x_j$ – a number of particles of a soil with heat conductivity $\lambda, \lambda, \ldots, \lambda$, and particle radius $r_1, r_2, \ldots, r_n$. $P_{ij}$ – the probability of the occurrence of all possible configurations of particles $(x_i, x_j)$ taking part in mass conducting. $f(x_i, x_j)$ denote the content of particular minerals, $V_{ij}$ – organic matter, $V_{ij}$ – water, $V_{ij}$, air, and $V_{ij}$ in the unit volume, $V_{ij}$.

The model was previously calibrated and verified based on data from the experiments and literature. The model performed satisfactorily the thermal conductivity of sand, loam, silt, clay, peat from various sites in comparison with data measured using stationary and non-stationary method.

### Results

Spatial characteristics of the experimental data for each soil property were determined using semivariograms. It was found that the thermal conductivity was mostly influenced by soil wetness, mineralogical composition, bulk density and organic matter content and less by soil temperature > 6°C, air pressure and humidity in the soil. At similar soil texture, the thermal conductivity was mostly influenced by soil wetness and bulk density. Differentiation in sand content had significant effect on spatial variability of the thermal conductivity. The semivariogram parameters of the thermal conductivity were related with spatial distribution of soil wetness and bulk density.

### Conclusion

The spatial variability of the soil thermal conductivity over cultivated fields is determined mainly by soil water content and bulk density values and their variation due to weather conditions, agricultural treatments and crops.

At the same spatial distribution of bulk density, the range of spatial autocorrelation of soil thermal conductivity was related to soil water content. At the field capacity it was similar to the range of bulk density, while for the lower water content, it was similar to the range of water content.

Spatial distribution pattern of the thermal conductivity resembled the bulk density distribution, and water content respectively at soil water contents close to field capacity and lower water contents.

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