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Thermal properties of peat, marshy and mineral soils in relation to soil moisture status in Polesie and Biebrza wetlands

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Knowledge of thermal properties of soil helps in estimating heat fluxes as an important component of the heat balance. The research was conducted to evaluate spatial distribution of the soil thermal properties (thermal conductivity, heat capacity and thermal diffusivity) in relation to soil wetness and bulk density in wetland soils of Polesie and Biebrza regions (Poland). Soil moisture content and bulk density together with soil temperature and texture data, were used for determination of thermal properties. The thermal conductivity was measured, by KD2 Pro Decagon, and calculated by the physical-statistical model of Usowicz, and the heat capacity – was calculated with empirical formulae, and the thermal diffusivity was determined by the ratio of thermal conductivity to the heat capacity. The thermal conductivity of wetland and marsh soils increases with increasing moisture content and density of the soil to higher extent in soils richer in minerals – mostly quartz. Maximum thermal conductivity of the wetland soils at different density did not exceed the value of the thermal conductivity of water. However, for mineral soil at the natural density (1.31 Mg m-3) and with the quartz content of 96%, the thermal conductivity is about four times greater than the thermal conductivity of water. This is due to that the thermal conductivity of quartz is sixteen times greater than that of water. Dependence of the soil thermal conductivity on moisture content is non-linear and the shape of the non-linearity largely depends on the density of the soil. Particular components of soil bring their contribution to the conductivity respectively to their fractions and compounds being dominant in the ground contribute mostly to the effective slope of the thermal conductivity versus the water content at a given soil density. The heat capacity of the soil substrate is linearly dependent on the water content. Soils containing more organic matter within low specific densities, usually are characterized by less or minimal available heat capacity values in dry conditions, while they can also be characterized by highest or maximal heat capacity values, in highly wet conditions approaching the saturation with water. The increase in soil density caused a parallel shift of the characteristics of the heat capacity in the direction of higher values. This was associated with an increase in solids content per unit volume of the substrate and the reduction of the water content and the specific heat capacity of the individual components of the soil. Thermal diffusivity of soils exhibits characteristic extremes. In organic soils characteristic minimal or maximal extremes may occur, while mineral soils achieve only maximal diffusivity values on regular basis. Extremes of the thermal diffusivity are mainly due to the changes in the intensity of the thermal conductivity of the substrate due to change in soil moisture content and density. The heat capacity of the soil increases with increasing moisture content at the constant rate. The value of soil thermal diffusivity depends highly on quartz content. Thermal diffusivity of the soil with the same moisture content was greater for the higher densities, and minimum or maximum thermal diffusivity tends to move toward the lower moisture content for higher densities. The observed extremes are so distinctive that they determine the value of soil moisture and density, at which the temperature wave travels the slowest and the fastest in the soil. The question of determining and sensing the water capacity is also affected by the texture and porosity. Simple volumetric measures of porosity are used, but with distinguishing the volume of pores filled by air and other part filled with water. Practically, porosity is treated simply and is included to assessments by effects on the thermal properties. We prove that thermal properties are very good variables for a sensitive indicator of the water content, and accounting the impact from porosity. Thermal properties gather effects from the texture and porosity cumulatively. Therefore they deserve on employing them in modeling and experimenting on the ground.