Specific Heat Capacity of Soil Minerals and Its Influence on Heat Pulse Measurement of Soil Water Content

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INTRODUCTION

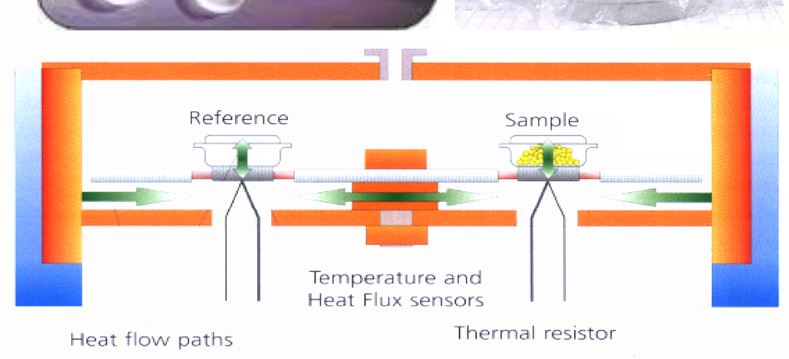
- The heat-pulse method has been used widely for measuring soil water content (θ). The accuracy of θ depends on the specific heat capacity of soil minerals (c_m). The value of c_m varies with soil texture and a range of data exists.
- For oven-dried (105°C) samples, specific heat capacity of soil solids (c_s) is determined by the specific heats of minerals, organic matter (OM), and tightly bound water.
- The objectives of this work are to: (1) partition the contributions of soil minerals, OM, and tightly bound water to c_s; (2) evaluate reliability of the commonly applied c_m value of 0.725 MJ Mg^{-1} °C^{-1} from de Vries (1963); and (3) investigate the influences of c_m value selection on θ measurements from the heat-pulse method.

MATERIALS & METHODS

- Samples: 9 soils with various textures and OM (Table 1).
- Specific surface area (SA) of samples: WP4-T dewpoint meter.
- Specific heat capacity of soil samples: differential scanning calorimetry (DSC).
  - c_s and $c_{s\text{-}200}$: samples with OM dried at 105°C and 200°C, respectively
  - c_m: OM-removed samples dried at 200°C
- Contributions of soil minerals, OM, and bound water to c_s were estimated using the de Vries (1963) model. Specific heat of OM was 1.92 MJ Mg^{-1} °C^{-1}.
- Heat-pulse θ were measured on repacked samples of soils 6, 8, and 9, with a θ range of 0.025 - 0.285 cm^3 cm^{-3}.

Table 1 Soil Samples

Soil	Texture	Clay	OM	SA
		%	g kg^{-1}	m^2 kg^{-1}
1	sand	5	0.9	6
2	sandy loam	7	8.6	29
3	silt loam	16	31.4	87
4	silt loam	18	12.4	57
5	silt loam	18	8.4	46
6	silt loam	22	20.1	73
7	silt loam	24	30.2	67
8	clay loam	30	2.7	88
9	silt clay	43	20.9	136



RESULTS & CONCLUSIONS

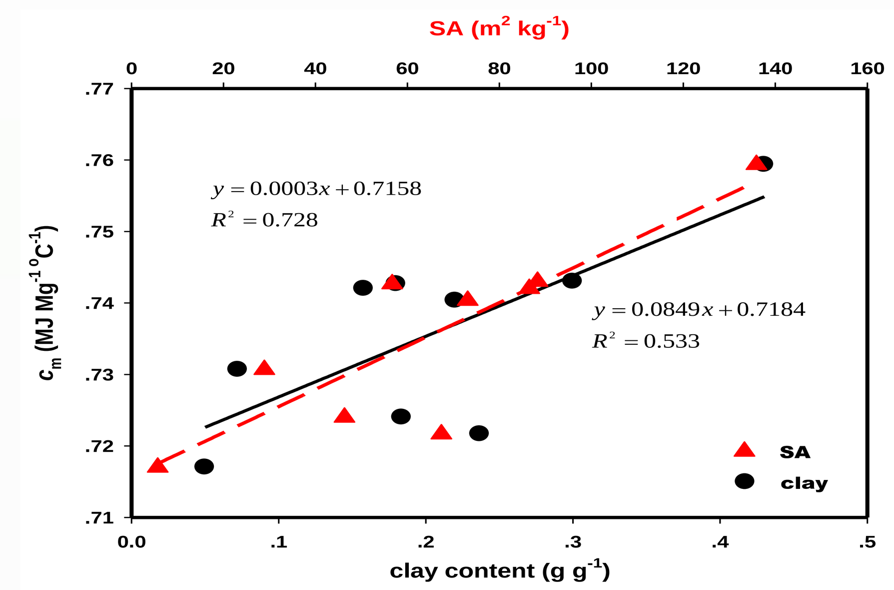


Fig. 1 Specific heat of soil minerals (c_m) as related to specific surface area (SA) and clay content of the samples.

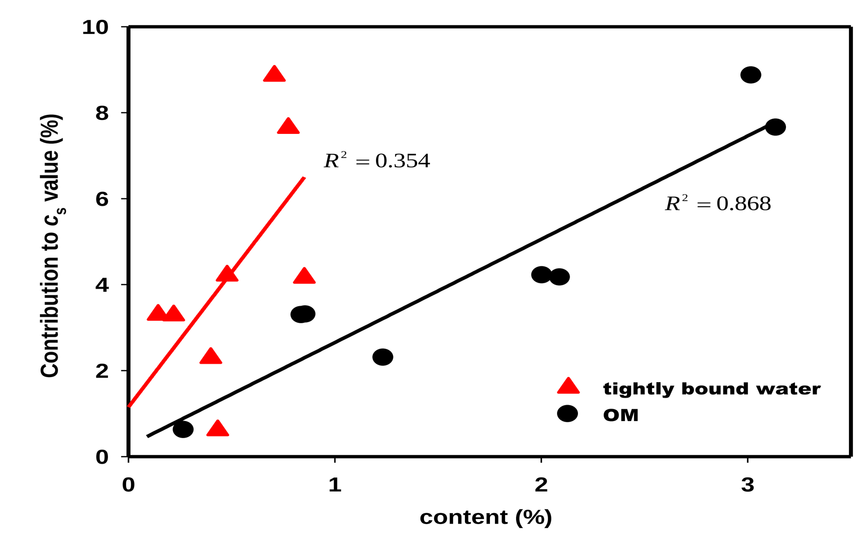


Fig. 2 Contributions of tightly bound water and organic matter (OM) to c_s as related to their contents.

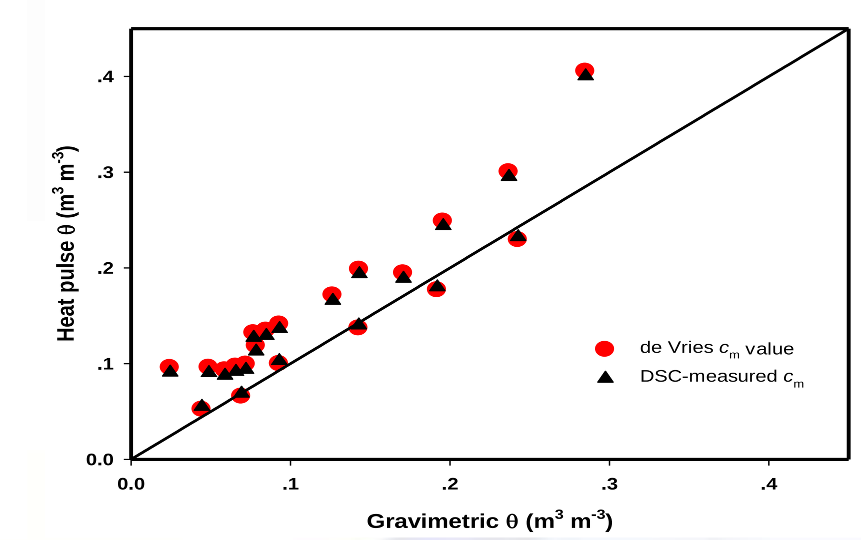


Fig. 3 Comparison of the heat-pulse θ (with c_m of 0.725 MJ Mg^{-1} °C^{-1} and c_m from DSC) versus gravimetrical θ.

- **Specific heat capacity of soil:**
  - c_m: a mean of 0.736 MJ Mg^{-1} °C^{-1} (0.717 - 0.759 MJ Mg^{-1} °C^{-1}). The common value of 0.725 MJ Mg^{-1} °C^{-1} (de Vries, 1963) slightly underestimated c_m.
  - c_s: a mean of 0.750 MJ Mg^{-1} °C^{-1} (0.718 - 0.772 MJ Mg^{-1} °C^{-1})
  - c_m and c_s correlates significantly to SA and clay content (Fig. 1). For improved accuracy, it may be necessary to estimate soil-specific c_m values from SA or clay content measurements.
- **Contributions of soil constituents to c_s:**
  - The contributions of OM and tightly bound water to c_s increased with their contents in the soil (Fig. 2). On average, soil minerals, OM, and tightly bound water accounted for about 95%, 3%, and 2% of c_s, respectively.
- **Soil θ measured with the heat-pulse technique:**
  - Heat-pulse θ was consistently higher than that of the gravimetric method (Fig. 3).
  - When the c_m value of 0.725 MJ Mg^{-1} °C^{-1} (de Vries, 1963) was replaced with DSC measured c_m values, the relative error in heat-pulse θ was reduced by 6%, 7%, and 10% for soils 6, 8, and 9, respectively.
  - Although θ accuracy with heat-pulse technique is improved with soil-specific c_m data, θ errors mainly come from other sources (e.g., uncertainties of heat-pulse measurements of volumetric heat capacity of bulk soil).

References:

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