Spatial and Temporal Variability of Soil Thermal Properties in A Tilled Layer

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Problem and Objectives

- Soil thermal properties are affected mainly by soil texture, water content (θ), bulk density (ρ_b), and structure formation.
- A tilled soil layer usually experiences age-hardening, frequent wetting-drying, and other process, thus exhibits high temporal and spatial variability in θ, ρ_b, and structure.

- Changes of soil thermal properties in response to the temporal and spatial variability of θ, ρ_b, and structure are not well understood.
- The objective of this research is to monitor the spatial and temporal characteristics of soil thermal properties in a tilled soil layer during the post-tillage period. Models are used to describe the dynamics of soil thermal properties as functions of soil texture, θ, and ρ_b.

Materials and Methods

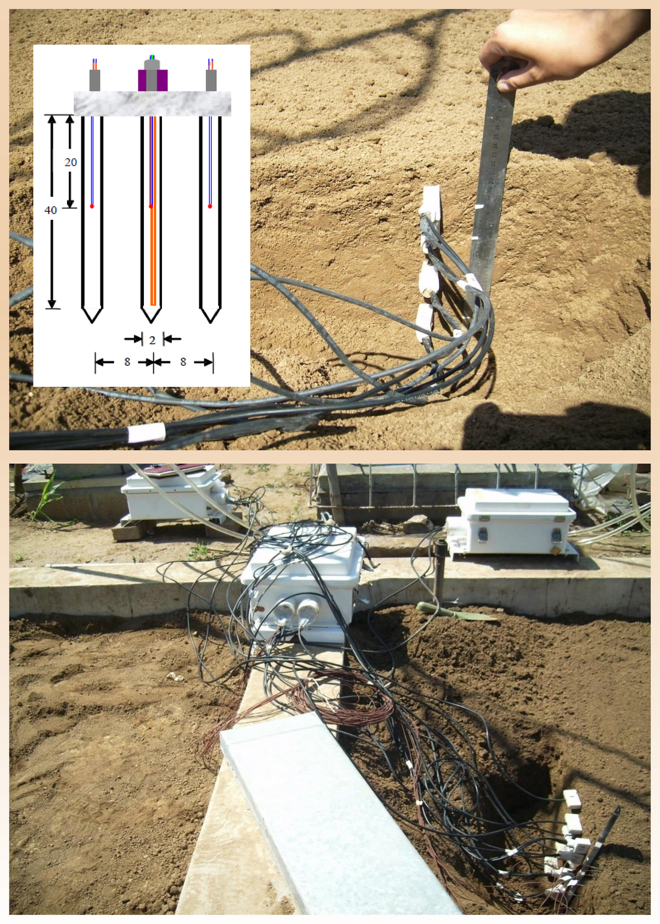
Thermo-Time Domain Reflectometry (T-TDR) technique

- Simultaneously measures soil thermal conductivity (λ) and volumetric heat capacity (*C*) with the heat-pulse method and θ with TDR technique.
- Soil bulk density ρ_b is estimated from *C* and θ measurements:

$$\rho_b = \frac{C - \rho_w c_w \theta}{c_s}$$

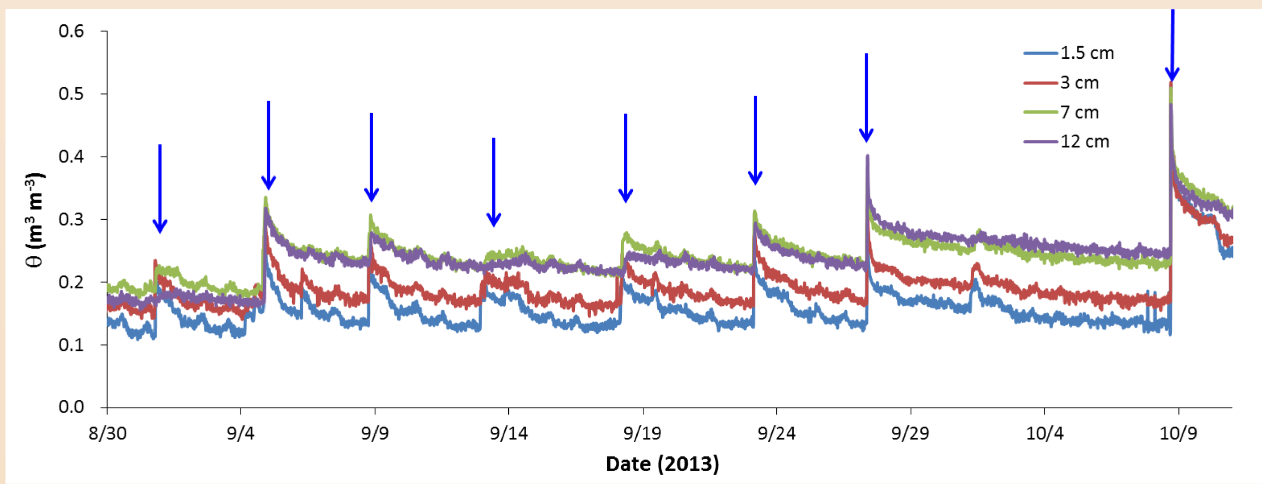
where $\rho_w c_w$ is heat capacity of water and c_s is specific heat of soil solids.

Field Experiment and Measurements



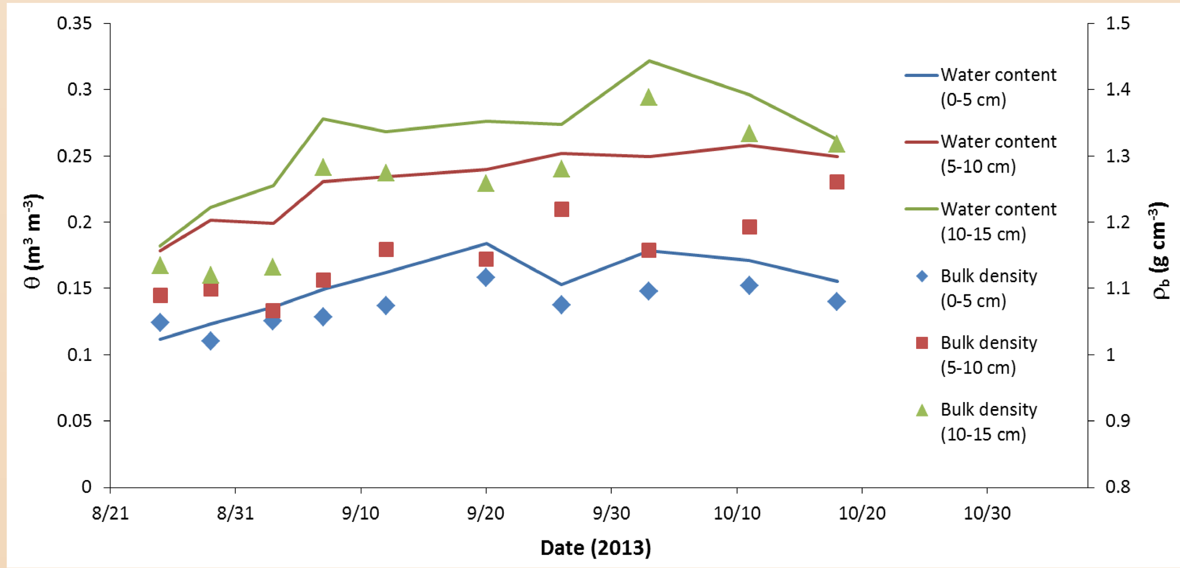
- Soil: a loam with 52% sand, 35% silt, and 13% clay
- Tillage: 0-20 cm, manually turned over
- θ: monitored with TDR at 1.5, 3, 7, and 12 cm
- ρ_b: T-TDR method and gravimetric sampling at 3, 7, and 12 cm depths
- λ and *C*: monitored with T-TDR, also determined on intact soil cores
- Wetting and drying cycles: natural rainfall combined with a rainfall simulator

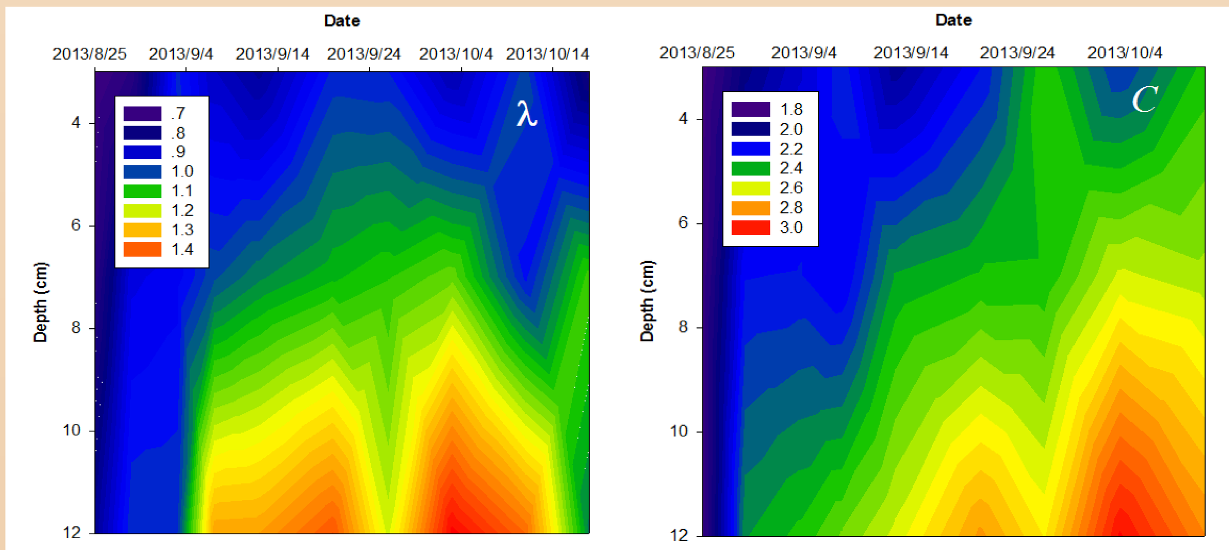
Results and Conclusions



Spatial and temporal changes of TDR θ in the post-tillage period. The blue arrows indicate natural and simulated rainfall events.

Spatial and temporal changes of gravimetric θ and ρ_b in the post-tillage period.



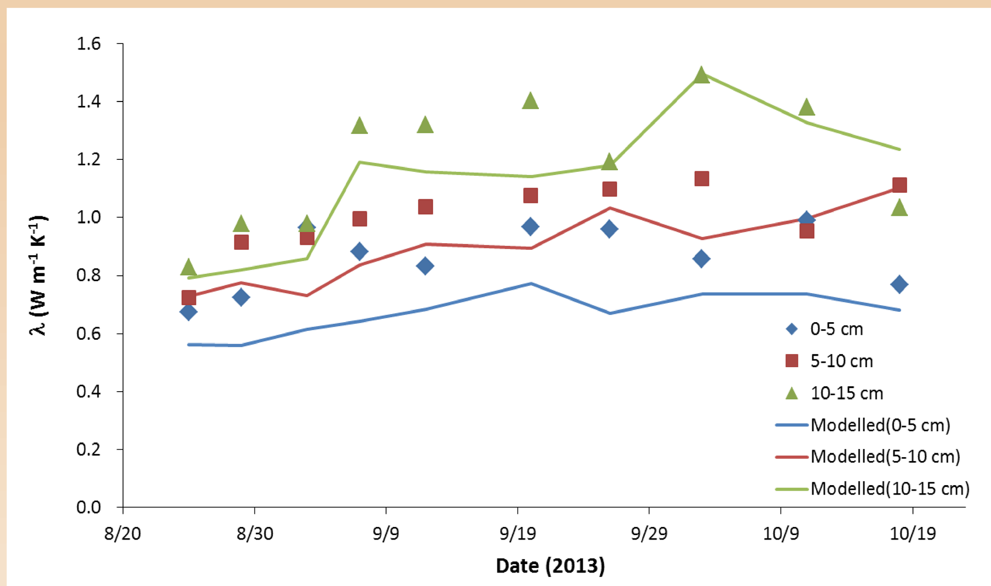


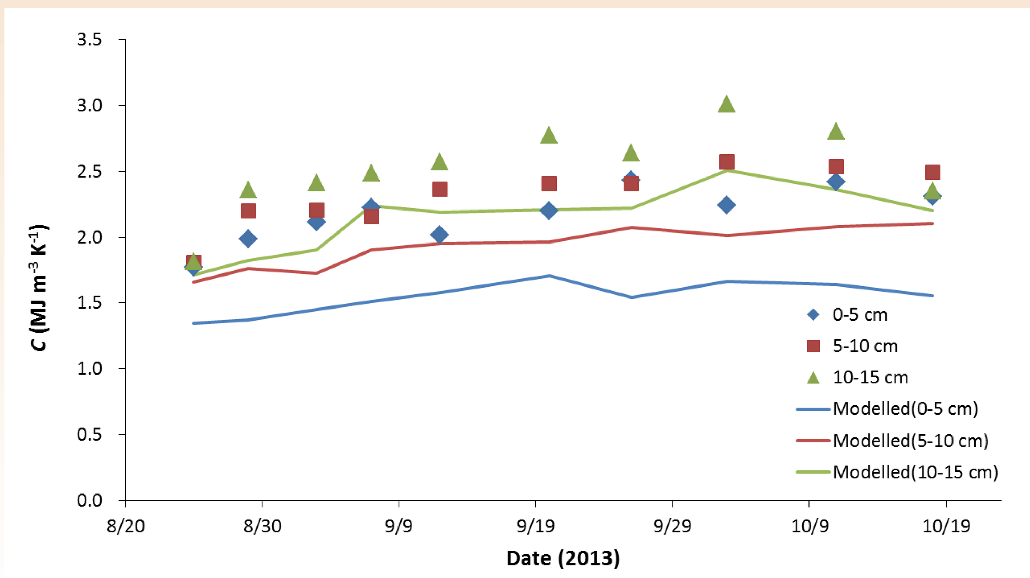
λ and *C* variations with time and depth as affected by changes of θ and ρ_b.

A new thermal conductivity model captured λ dynamics as affected by soil texture, θ, and ρ_b.

$$\lambda = \lambda_d + \exp(\beta - \theta^{-\alpha})$$
$$\lambda_d = -0.56n + 0.51$$
$$\alpha = 0.8\theta_{clay} + 0.2$$
$$\beta = 1.2\rho_b(\theta_{sand} + 1) - 2\theta_{sand} + 0.15$$

λ_d: dry soil thermal conductivity
n: soil porosity





Spatial and temporal changes of *C* are described by the modified de Vries (1963) model.

$$C = \rho_b c_s + \rho_w c_w \theta$$

c_s: specific heat of soil solids
$\rho_w c_w$: specific heat of free water

Reference: Liu Xiaona, Tusheng Ren, and Robert Horton. 2008. Determining soil bulk density with thermo-time domain reflectometry sensors. Soil Sci. Soc. Am. J. 72:1000-1005.

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