Multilayer matric flux potential to predict transpiration reduction in cropped soils in southeast Brazil

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Introduction and Objective

Hydraulic properties determine the ability of soils to supply water to plants and together with root length architecture and atmospheric demand control the amount of root water uptake. Robust soil hydraulic parameterization (*from nearly saturated to dry soil*) is of paramount importance in studies of soil-water availability. We evaluated the general hydraulic pattern of two different soils in their ability to provide transpirable water to rainfed crops. The evaluation was based on two approaches: **(1)** calculating a limiting matric flux potential and **(2)** simulating relative transpiration by a process-based agro-hydrological model.

Materials and Methods

Soil hydraulic properties

Soil hydraulic properties of two representative soils (**Table 1** and **2**) of southeast Brazil were obtained through inverse solution (Hydrus-1D, Šimůnek et al., 2016) using data from evaporation experiments with soil-water content monitored by attenuation of a collimated γ-ray.

Table 1 – Soil texture data for the two studied soils

Soil ID	depth (cm)	Sand%	Silt%	Clay%	Texture class
1	0-15	84	3	14	Sandy Loam
	30-45	84	1	15	
2	0-15	18	13	69	Clay
	30-45	14	11	75	

Table 2 – Van Genuchten – Mualem parameters for both layers of the two studied soils

Soil	depth (cm)	α (m^{-1})	n	θ_r	θ_s	K_s (m d^{-1})	l
Sand	0-15	0.639	1.598	0.012	0.332	0.142	0.216
	30-45	15.399	1.732	0.011	0.365	1.665	0.000
Clay	0-15	1.898	1.400	0.000	0.385	0.040	0.085
	30-45	6.726	1.460	0.000	0.397	0.068	0.288

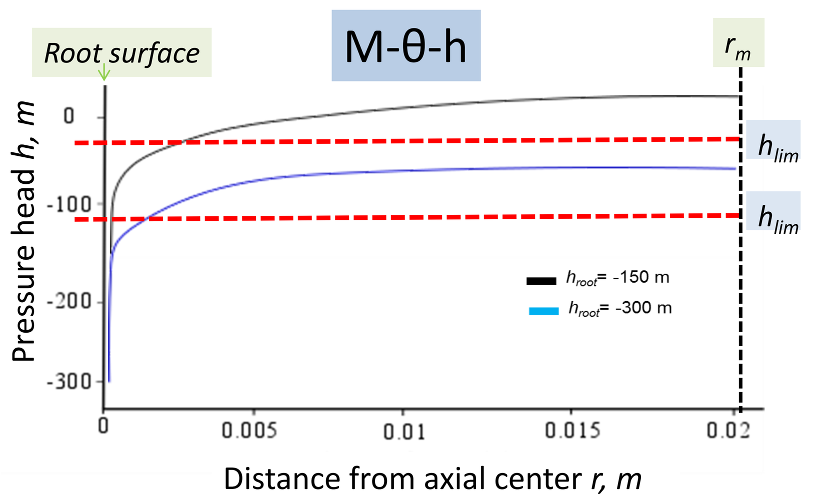
Limiting matric flux potential (M_{lim})

An earlier developed multilayer approach of limiting matric flux potential takes into account three important factors that determine plant transpiration: transpiration (***T_p***), root length per volume soil (***R***) and soil hydraulic properties (***SHP***),equations [**1**] and [**2**] (Pinheiro et al., 2017):

$$M = \int_{h_{root}}^{h} K(h)dh \qquad (1)$$

$$M_{lim}(z) = \frac{p^* T_p}{\pi \int_0^{D_{root}} R dz} \qquad (2)$$

where: p = 5.3 ; D_{root} = rooting depth.



Agro-hydrological simulations

The SWAP model (Kroes et al., 2008) was parameterized for soil hydraulic properties (**Table 2**), crop growth (simple module) and meteorological conditions. Two years with different water availability during the crop season (**low and average rainfall**) were selected. For both soils and years, the crop season started on Feb/1 and ended on May/31. The *Feddes reduction function* (Feddes et al., 1978) was used and its parameters were set according to Taylor and Ashcroft (1972): h_{3l} = - 600 cm, h_{3h} = -400 cm and h_4 = -8000 cm. For intermediate values of T_p (between 1 and 5 mm d^{-1}), the value of h_3 is linearly interpolated between h_{3l} and h_{3h}.

Results and Discussion

The general hydraulic behavior of the studied soils is presented in Figures 1-4 and Table 3.

Limiting matric flux potential

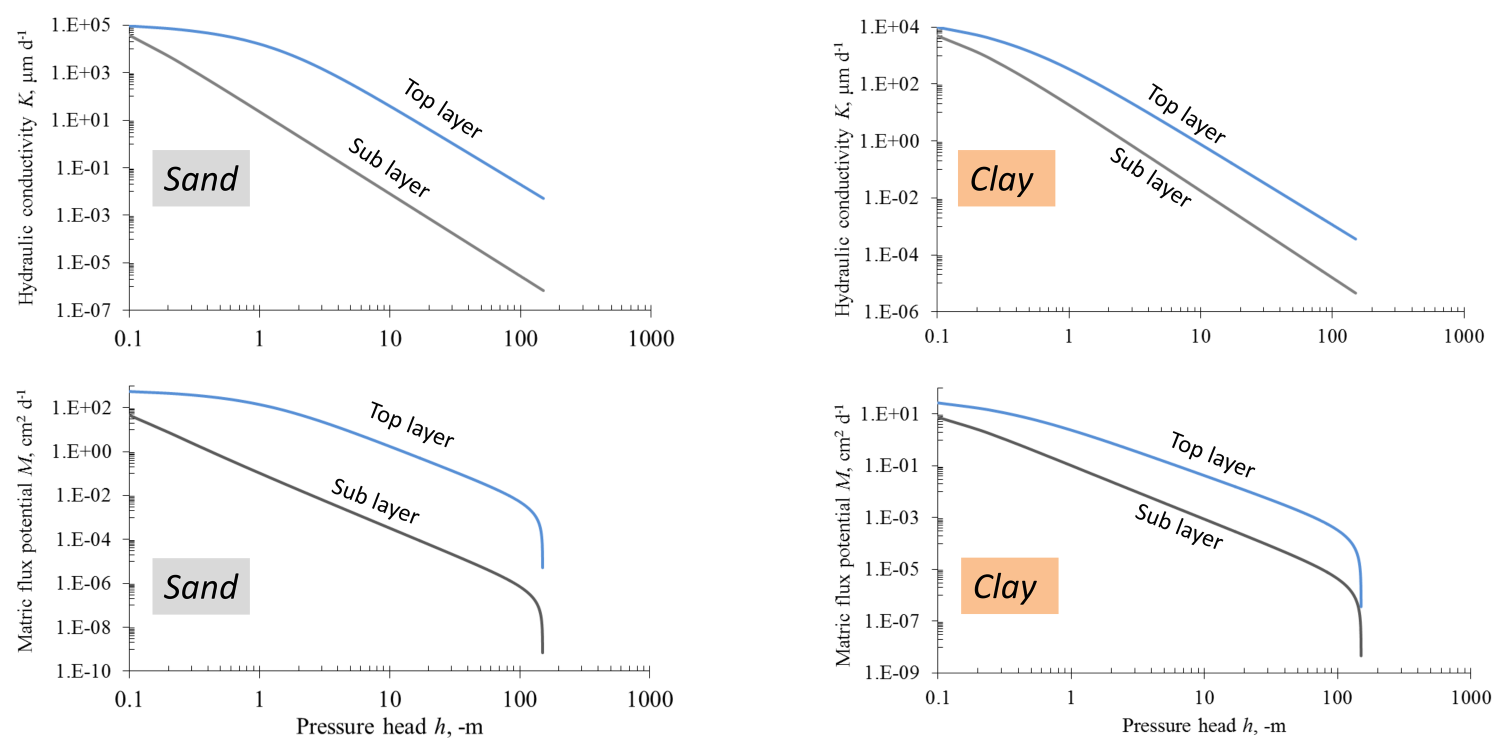


Figure 1 – Hydraulic conductivity (K) and matric flux potential (M for h_{root} = -150 m) for the studied soils

Table 3 – Bulk soil limiting pressure head (h_{lim}) obtained from M-θ-h relation for two transpiration rates and two values of root water potential (h_{root})

Soil	Layer	T_p = 5 mm d^{-1}, h_{root} = - 80 m	T_p = 5 mm d^{-1}, h_{root} = - 150 m	T_p = 1 mm d^{-1}, h_{root} = - 80 m	T_p = 1 mm d^{-1}, h_{root} = - 150 m
		h_{lim}			
Sand	0-15	-49.0	-55.0	-69.0	-96.0
	30-45	-1.6	-1.6	-3.0	-3.0
Clay	0-15	-12.0	-12.0	-27.0	-28.0
	30-45	-1.7	-1.7	-4.0	-4.0

Agro-hydrological simulations

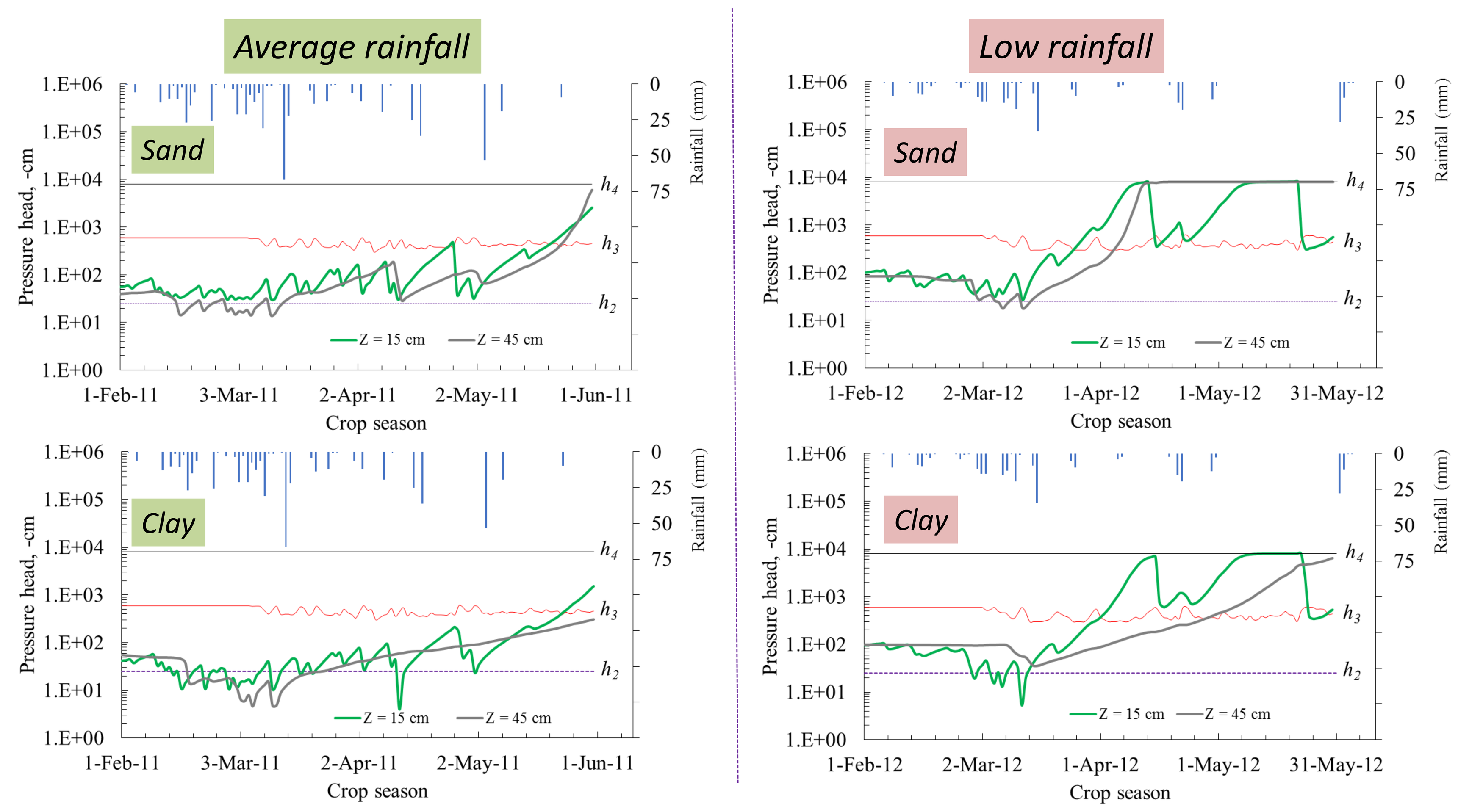


Figure 2 – Pressure head at two soil depths for both soils cropped with maize under rainfed conditions.

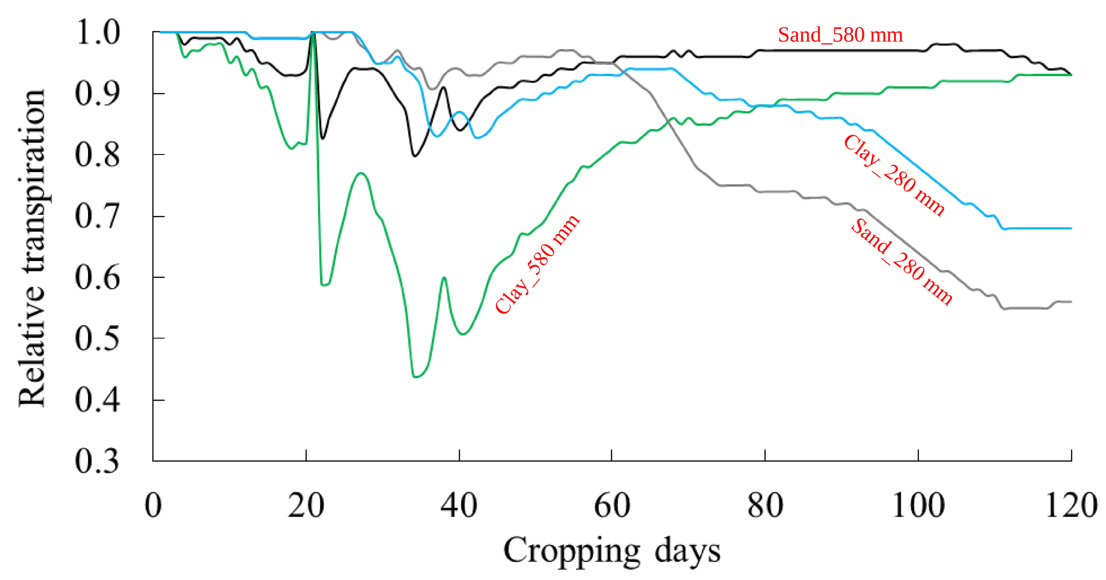


Figure 3 – Simulated relative transpiration for maize in low and average rainfall seasons.

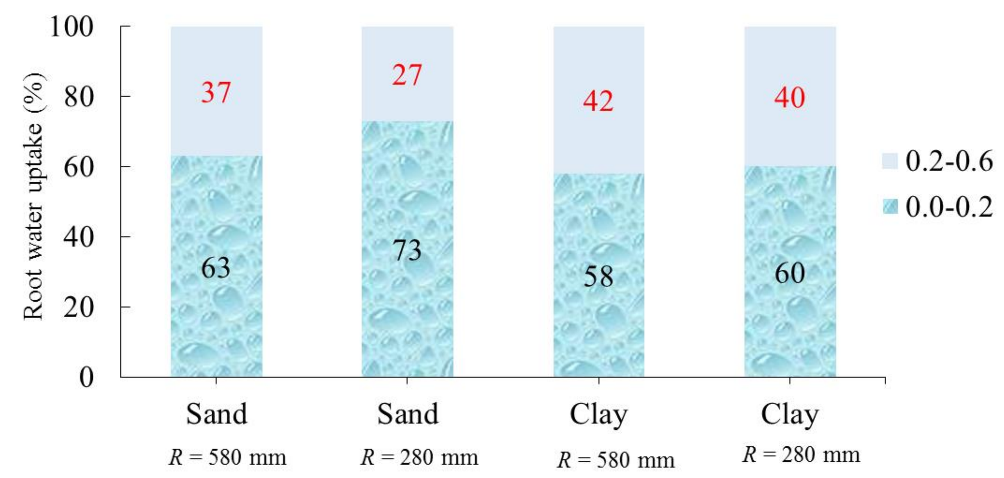


Figure 4 – Relative distribution of soil water uptake over depth for sand and clay soil.

Conclusions

1. The used methodology was able to detect the hydraulic differences between soils affecting water supply to crops.
2. Root water uptake of the sandy soil occurred mostly from the surface layer, while for the clay soil the water extraction was more homogeneously distributed, leading to higher relative yield for rainfed crops.

Cited literature

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