DUAL POROSITY EFFECTS IN HYDROLOGICAL PERFORMANCE OF EXTENSIVE GREEN ROOFS

EGU 2021 DISPLAY MATERIALS

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CTU IN PRAGUE

1 FACULTY OF CIVIL ENGINEERING

2 UNIVERSITY CENTRE FOR ENERGY EFFICIENT BUILDINGS

LOCATION

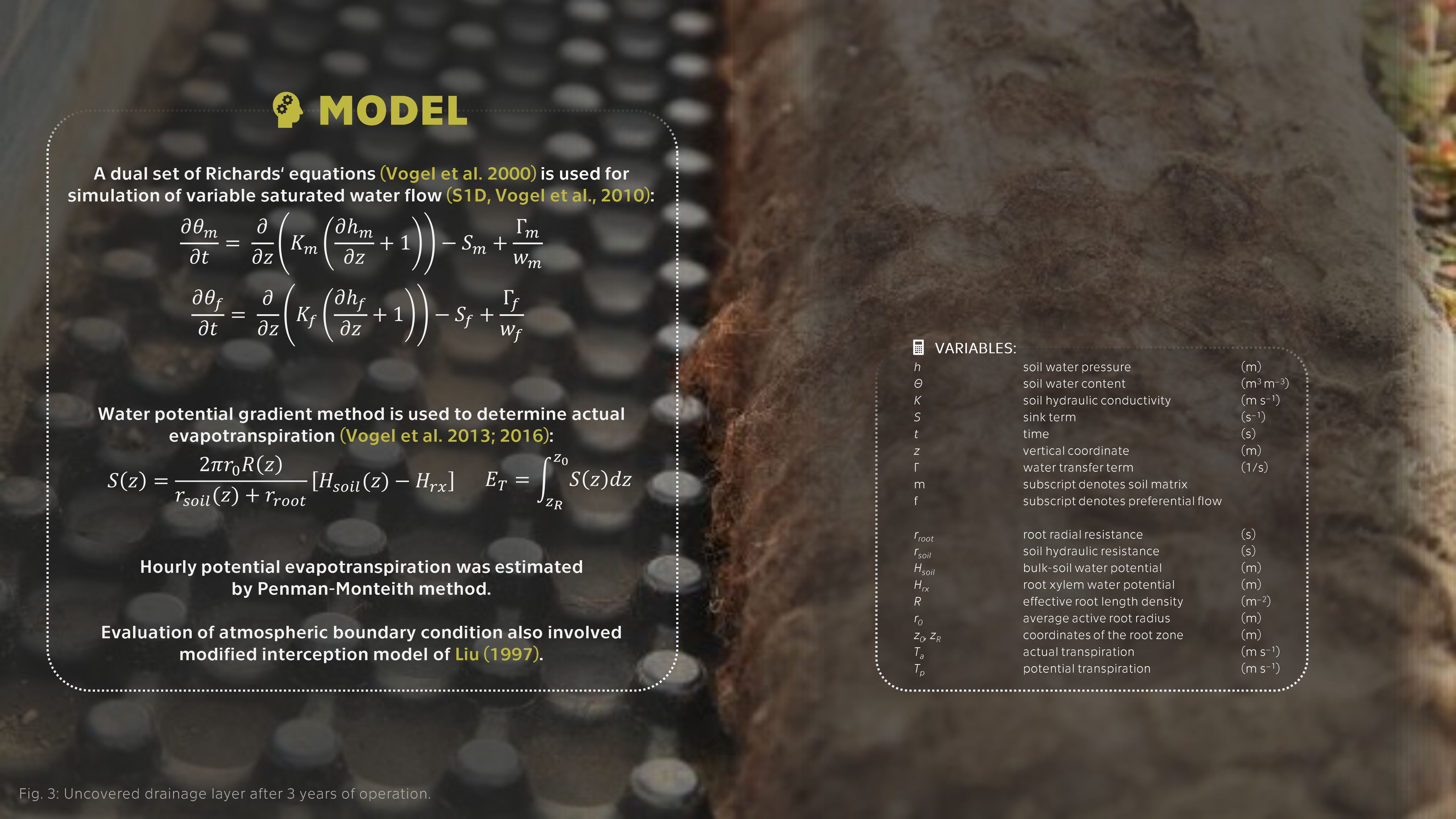
- extensive green roof of University Centre for Energy Efficient Buildings (UCEEB), Bustehrad, Czechia (Fig. 1)
- average annual precipitation total 500 mm, average annual temperature 8°C
- site equipment – rain gauge, soil and air temperature probes, wind speed and direction, relative humidity of the air, and net radiation (Fig. 2)

INTRODUCTION

The admixture of light porous minerals such as pumice or expanded clay in artificial substrates could lead to dual porosity character of substrates and may affect their retention properties. The dual-continuum model S1D is used to assess water flow in extensive green roof test beds with artificial substrate. The model numerically solves dual set of Richards' equations. The soil hydraulic properties are described using van Genuchten-Mualem approach. Selected model parameters were optimized using Levenberg-Marquardt algorithm.

Fig. 1: Experimental site on the roof of the building with four green roof test beds.

Fig. 2: University Centre for Energy Efficient Buildings (UCEEB), Bustehrad, Czechia.



MODEL

A dual set of Richards' equations (Vogel et al. 2000) is used for simulation of variable saturated water flow (S1D, Vogel et al., 2010):

$$\frac{\partial \theta_m}{\partial t} = \frac{\partial}{\partial z}\left(K_m\left(\frac{\partial h_m}{\partial z} + 1\right)\right) - S_m + \frac{\Gamma_m}{w_m}$$

$$\frac{\partial \theta_f}{\partial t} = \frac{\partial}{\partial z}\left(K_f\left(\frac{\partial h_f}{\partial z} + 1\right)\right) - S_f + \frac{\Gamma_f}{w_f}$$

Water potential gradient method is used to determine actual evapotranspiration (Vogel et al. 2013; 2016):

$$S(z) = \frac{2\pi r_0 R(z)}{r_{soil}(z) + r_{root}}\left[H_{soil}(z) - H_{rx}\right] \qquad E_T = \int_{z_R}^{z_0} S(z)dz$$

Hourly potential evapotranspiration was estimated by Penman-Monteith method.

Evaluation of atmospheric boundary condition also involved modified interception model of Liu (1997).

VARIABLES:

h	soil water pressure	(m)
Θ	soil water content	($m^3\,m^{-3}$)
K	soil hydraulic conductivity	($m\,s^{-1}$)
S	sink term	(s^{-1})
t	time	(s)
z	vertical coordinate	(m)
Γ	water transfer term	(1/s)
m	subscript denotes soil matrix	
f	subscript denotes preferential flow	
r_{root}	root radial resistance	(s)
r_{soil}	soil hydraulic resistance	(s)
H_{soil}	bulk-soil water potential	(m)
H_{rx}	root xylem water potential	(m)
R	effective root length density	(m^{-2})
r_0	average active root radius	(m)
z_0, z_R	coordinates of the root zone	(m)
T_a	actual transpiration	($m\,s^{-1}$)
T_p	potential transpiration	($m\,s^{-1}$)

Fig. 3: Uncovered drainage layer after 3 years of operation.

EXPERIMENTAL SETUP

- observed test beds (effective dimension 1 x 1 m^2, Fig. 4) consist of typical extensive green roof layers (Fig. 5) and metal structure,
- outflow is measured by tipping bucket flowmeters, the moisture content within the soil substrate by TDR probes, one of the test beds is weighted
- pre-grown sedum carpet or sedum cuttings were applied as vegetation cover
- test beds are filled with commercial soil substrate – a mixture of spongilite (55 %), crushed expanded clay (30 %) and peat (15 %)
- among others, Flores-Ramirez et al. (2018) reported bimodal character of the spongilite and expanded clay retention curve

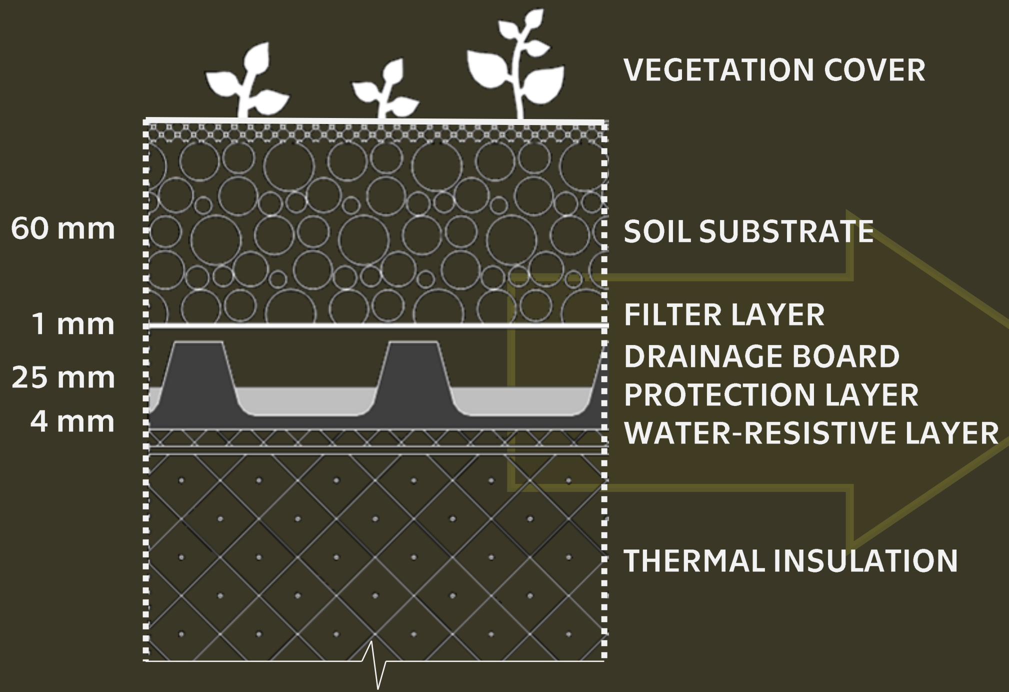


Fig. 3: Vertical profile of the test bed.

The simplified vertical profile for the model purposes.

Fig. 4: One of the test beds.

STUDIED PERIOD

- from 15th of May to 31th of May
- precipitation amount = 49.4 mm
- observed outflow from test bed:

  ACu = 15.1 mm (Fig. 6)

TEST BED ACu

Fig. 6: Hydrological response of the test bed ACu was chosen to assess. The abbreviation ACu refer to used soil substrate ACRE and initial vegetation cover sedum cuttings.

USED PARAMETERS

Bimodal character of the studied soil admixtures is represented by single domain or two domains respectively. Hydraulic parameters of the domains described using van Genuchten-Mualem approach.

SINGLE DOMAIN SCENARIO

θ_r (–)	θ_s (–)	α (1/cm)	n (–)	K_s (cm/d)
0.00	**0.293**	**0.495**	**1.86**	**671**
0.00	0.169	0.450	2.70	5000

DUAL DOMAIN SCENARIO

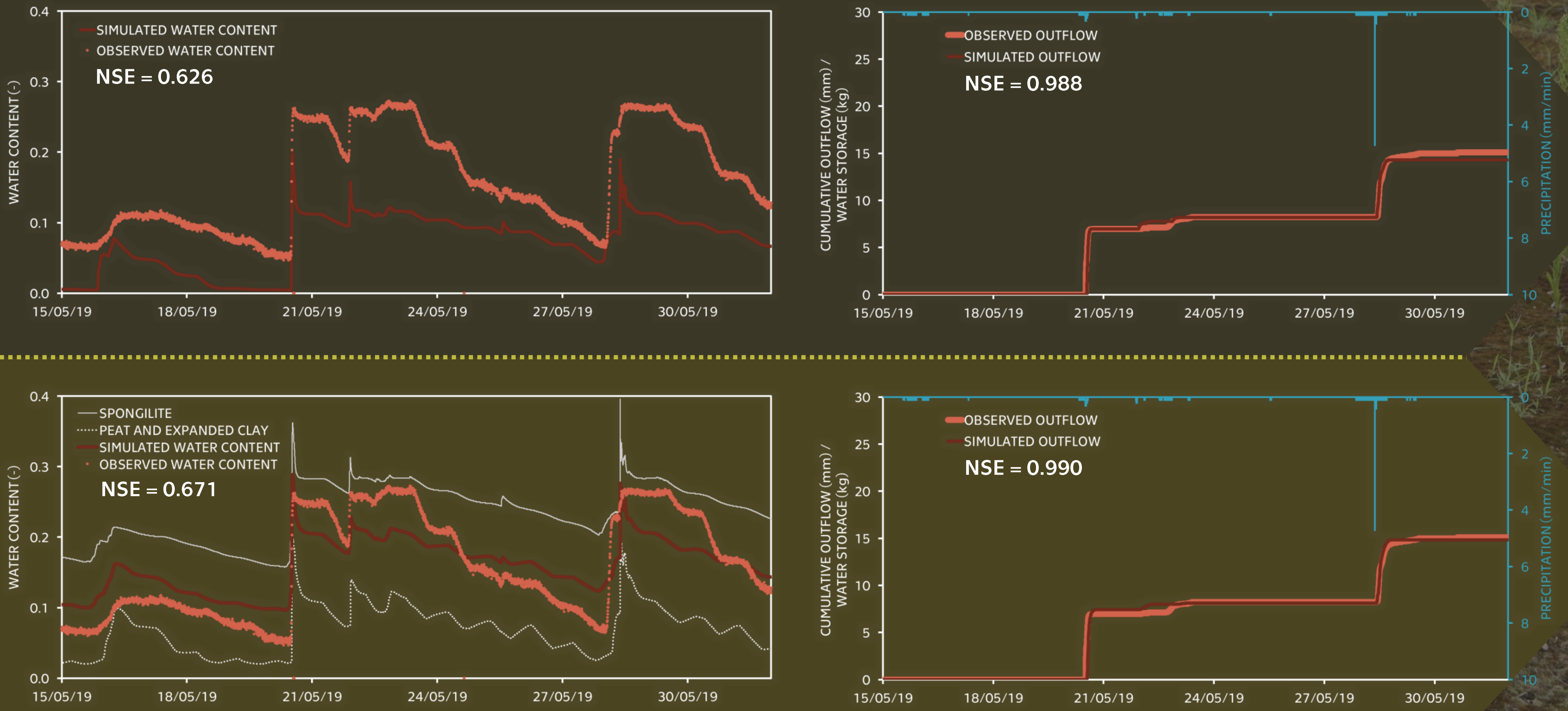
θ_r (–)	θ_s (–)	α (1/cm)	n (–)	K_s (cm/d)
THE FIRST DOMAIN 45 % – PEAT AND CRUSHED EXPANDED CLAY				
0.00	**0.200**	**0.504**	**1.57**	**32**
0.00	0.169	0.450	2.70	5000
THE SECOND DOMAIN 55 % – SPONGILITE				
0.00	**0.500**	**0.331**	**1.73**	**1100**
0.00	0.169	0.450	2.70	5000

Tab. 1: Model parameters for both scenarios. Selected parameters (formatted in bold) were optimized using Levenberg-Marquardt algorithm (Doherty et al. 2014).

CURRENT RESULTS

- simulated outflow and water content are compared with measured counterparts in the test beds ACu (Fig. 7)
- although outflow prediction is very good in both cases (NSE over 0.98), dual-continuum model provided better description of water content
- parameters of dual-continuum model better fit to measured retention curve parameters (not shown here)
- simulations for longer time periods and other test beds need to be done to confirm or disprove the assumption of bimodal soil substrate character

Fig. 7: Model results for dual-continuum model and single-continuum model, respectively.



SINGLE DOMAIN SCENARIO

DUAL DOMAIN SCENARIO

CONCLUSIONS

Dual-continuum model provides higher flexibility and overall better agreement between measured and simulated variables (according to standard performance measures). Further investigation of hydrological regime of such substrates and possible effects of soil water retention hysteresis of their curve is needed.

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AUTOR'S RESEARCHGATE LINK

DUAL POROSITY EFFECTS IN HYDROLOGICAL PERFORMANCE OF EXTENSIVE GREEN ROOFS

EGU 2021 vPICO LIVE PRESENTATION

ASSESING DUAL POROSITY EFFECTS OF ARTIFICIAL SUBSTRATES BY INVERSE MODELING

LOCATION:
UCEEB BUILDING, BUSTEHRAD, CZECHIA

PHYSICALLY BASED ONE–DIMENSIONAL MODEL

DUAL-CONTINUUM MODEL PROVIDES HIGHER FLEXIBILITY AND OVERALL BETTER AGREEMENT BETWEEN MEASURED AND SIMULATED VARIABLES

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