S1: Soil Water Retention Curve modelling steps and procedures

The bimodal van Genuchten model of Durner (Durner, 1994) was chosen for the retention fitting:

$$S_e(h) = \sum_{i=1}^{2} \omega_i \left[\frac{1}{1+(\alpha_i|h|)^{n_i}}\right]^{1-\frac{1}{n_i}} \qquad \text{Eq. (1)}$$

where ω_1 [-] and ω_2 [-] ($\omega_1 + \omega_2 = 1$) are the weight of each sub-function. Each of the sub-functions has its own shape parameters: α_i [cm^{-1}] that is related to the inverse of the air-entry pressure, and n_i [-] that controls both the shape of the retention curve at the air-entry region and the asymptotic curvature towards the residual water content.

The Mualem's predictive model (Mualem, 1976) was chosen for the saturated hydraulic conductivity (K_s) fitting. It predicts the shape of the conductivity function from the shape of the retention function.

$$K_r\big(S_e(h)\big) = S_e^{\tau} \left[\frac{\int_0^{Se} h^{-1} dS_e(h)}{\int_0^{1} h^{-1} dS_e(h)}\right]^2 \qquad \text{Eq. (2)}$$

where τ [-] is a tortuosity parameter.

The combination of the bimodal Durner retention function with the Mualem's K-model yields to (Priesack and Durner, 2006):

$$K(h) = K_s \left[\sum_{j=1}^{2} \omega_j \left[1 + \left(\alpha_j|h|\right)^{n_j}\right]^{\frac{1}{nj}-1}\right]^{\tau} \cdot \left[\frac{\sum_{j=1}^{2} \omega_j\alpha_j\left\{1-(\alpha_j|h|)^{n_j-1}\left[1+(\alpha_j|h|)^{n_j}\right]^{\frac{1}{nj}-1}\right\}}{\sum_{j=1}^{2} \omega_j\alpha_j}\right]^2 \qquad \text{Eq. (3)}$$

where j are indices for the parameters of each van Genuchten function, and ω_j are the weights of both partial functions. The following restriction applies: $0 < \omega_j < 1$ and $\Sigma\ \omega_j = 1$.

Durner, W.: Hydraulic conductivity estimation for soils with heterogeneous pore structure, Water Resour Res., 30, 211-223, 1994

Mualem, Y.: A new model for predicting the hydraulic conductivity of unsaturated porous media, Water Resour Res., 12, 513-522, 1976

Priesack, E. and Durner, W.: Closed-Form Expression for the Multi-Modal Unsaturated Conductivity Function, Vadose Zone Journal, 5(1), 121-124, 2006

S2: Calculation of additional parameters

Total porosity ϕ [%] was calculated as follows:

$$\phi = 1 - (\rho_b/\rho_p) \quad \text{Eq. (4)}$$

where ρ_b is the soil bulk density [g cm^{-3}] and ρ_p is a default particle density of 1.6 g cm^{-3}.

Air capacity ε [%] was calculated as follows (Reynolds et al., 2009):

$$\varepsilon = \phi - \theta_{fc} \quad \text{Eq. (5)}$$

where ϕ is the total porosity [%] and θ_{fc} the water content at field capacity [%].

Soil pore size from and above which water was withdrawn at a pressure step pF [-] was calculated as follows (Reynolds et al., 2009):

$$r_i = \left(\frac{2*\sigma*\cos\alpha}{P_i}\right) = \left(\frac{2*\sigma*\cos\alpha}{\rho*g*\left(\frac{10^{pF_i}}{100}\right)}\right).10^9 \quad \text{Eq. (6)}$$

where r is the tube or pore radius [nm], σ is the surface tension of water (72.75 10^{-3} J m^{-2} at 20 ºC), α is the contact angle which is here assumed to be zero, P is the water pressure [Pa], ρ is the water density (10^3 g m^{-3} at 20 ºC), g the acceleration due to gravity (9.80 m s^{-2}) and P_F = $\log_{10}$(h).

Soil pores were classified into three size fractions: macropores (r > 50 nm), mesopores (50 ≥ r > 2 nm), and micropores (r ≤ 2 nm) (Kuila and Prasad, 2013; Wang et al., 2020).

Kuila, U. and Prasad, M.: Specific surface area and pore-size distribution in clays and shales, Geophys Prospect., 61, 341-362, 2013

Reynolds, W. D., Drury, C. F., Tan, C. S., Fox, C. A., and Yang, X.M.: Use of indicators and pore volume-function characteristics to quantify soil physical quality, Geoderma, 152, 252-263, 2009

Wang, H., Tan, J., Ge, Y., Li, J., Yan, X., Wang, C. et al.: Pore morphology and fractal dimension of ash deposited in catalyst diesel particulate filter, Environmental Science and Pollution Research, 2020

Table S3: Soil physical and hydraulic data for DS

Depth	Rep	Sand	Silt	Clay	Texture	ρ_b	α_1	n_1	α_2	n_2	ω_2	θ_r	θ_s	E_{RMS} θ	K_s	E_{RMS} K_s	ϕ	macro	meso	micro	ε
		%	%	%		g cm^{-3}	cm^{-1}	-	cm^{-1}	-	-	cm^3 cm^{-3}	cm^3 cm^{-3}		cm d^{-1}		%	%	%	%	%
5-10 cm	1	56.43	32.22	11.35	Sandy Loam	0.85	0.500	1.470	0.002	1.262	0.658	0.00	0.69	0.0053	4 110	0.1351	67	53	9	3	18
	2					1.05	0.002	1.418	0.391	1.486	0.423	0.00	0.55	0.0050	567	0.1886	60	49	5	1	23
	3					0.80	0.167	6.267	0.016	1.248	0.822	0.13	0.65	0.0325	3	0.9046	69	43	5	2	19
	4					**0.84**	**0.500**	**1.816**	**0.004**	**1.256**	**0.618**	**0.00**	**0.63**	0.0024	**1 914**	0.1033	68	51	7	3	28
30-35 cm	1	57.30	32.24	10.46	Sandy Loam	0.94	0.500	1.497	0.004	1.303	0.459	0.12	0.63	0.0089	23	0.4920	64	44	4	1	24
	2					1.04	0.284	1.174	0.001	1.591	0.610	0.00	0.60	0.0033	396	0.1467	60	50	6	2	09
	3					**0.86**	**0.177**	**2.159**	**0.090**	**1.135**	**0.737**	**0.00**	**0.51**	0.0058	**2 892**	0.0746	67	38	5	3	36
	4					0.95	0.500	1.010	0.500	1.381	0.943	0.27	0.57	0.0116	7	0.2474	63	28	1	0	27

Data indicated in bold are soil core data used as input parameters in Hydrus

Table S4: Soil physical and hydraulic data for MS

Depth	Rep	Sand	Silt	Clay	Texture	ρ_b	α_1	n_1	α_2	n_2	ω_2	θ_r	θ_s	E_{RMS} θ	K_s	E_{RMS} K_s	ϕ	macro	meso	micro	ε
		%	%	%		g cm^{-3}	cm^{-1}	-	cm^{-1}	-	-	cm^3 cm^{-3}	cm^3 cm^{-3}		cm d^{-1}		%	%	%	%	%
5-10 cm	1	47.63	37.05	15.32	Loam	1.07	0.005	1.231	0.500	1.738	0.326	0.00	0.67	0.0045	7 762	0.1932	59	53	8	3	13
	2					1.31	0.231	1.303	0.001	1.602	0.522	0.00	0.47	0.0056	1 480	0.1994	50	43	4	1	15
	3					1.13	0.320	1.522	0.004	1.214	0.630	0.00	0.57	0.0039	2 251	0.1582	57	43	7	3	17
	4					**1.30**	**0.001**	**1.449**	**0.191**	**1.198**	**0.483**	**0.00**	**0.51**	0.0028	**431**	0.1464	50	40	7	2	09
30-35 cm	1	39.86	44.41	15.72	Loam	**1.40**	**0.306**	**1.311**	**0.001**	**1.629**	**0.410**	**0.00**	**0.44**	0.0026	**1 038**	0.0793	46	39	3	1	18
	2					1.25	0.000	1.010	0.047	1.753	0.904	0.27	0.47	0.0330	0	0.9291	52	18	0	0	15
	3					1.31	0.500	1.400	0.001	1.298	0.516	0.00	0.48	0.0051	1 468	0.0932	50	38	6	2	19
	4					1.12	0.195	1.236	0.000	1.498	0.269	0.00	0.52	0.0032	6 464	0.0841	57	43	6	2	22

Data indicated in bold are soil core data used as input parameters in Hydrus

S5: Detailed description of hydraulic parameters

Soil ρ_b at DS ranged from 0.80 to 1.05 g cm^{-3} in shallow soil cores (5 to 10 cm) and from 0.86 to 1.04 g cm^{-3} in deep soil cores (30 to 35 cm). At MS, shallow soil ρ_b ranged from 1.07 to 1.31 g cm^{-3} and deeper soil ρ_b from 1.12 to 1.40 g cm^{-3}. Average soil ρ_b increased with depth (not significantly) in each site: from 0.89 ± 0.05 to 0.95 ± 0.03 g cm^{-3} at DS, and from 1.20 ± 0.05 to 1.27 ± 0.05 g cm^{-3} at MS. Average soil ρ_b was higher (not significantly) at MS than DS for both shallow and deeper soil cores.

Shallow soil θ_s at DS ranged from 0.55 to 0.69 cm^3 cm^{-3} and from 0.51 to 0.63 cm^3 cm^{-3} in deeper soil. At MS, values ranged from 0.47 to 0.67 cm^3 cm^{-3} in shallow soil and from 0.44 to 0.52 cm^3 cm^{-3} in deeper soil. Average soil θ_s decreased with depth (not significantly) in each site: from 0.63 ± 0.03 to 0.58 ± 0.02 cm^3 cm^{-3} at DS, and from 0.55 ± 0.04 to 0.48 ± 0.02 cm^3 cm^{-3} at MS. Average soil θ_s was higher (not significantly) at DS than MS for both shallow and deeper soil cores.

Shallow soil θ_r at DS ranged from 0.00 to 0.13 cm^3 cm^{-3} and from 0.00 to 0.27 cm^3 cm^{-3} in deeper soil. At MS, values were equal to 0.00 cm^3 cm^{-3} in shallow soil and ranged from 0.00 to 0.27 cm^3 cm^{-3} in deeper soil. Average soil θ_r increased with depth (not significantly) in each site: from 0.03 ± 0.03 to 0.10 ± 0.06 cm^3 cm^{-3} at DS, and from 0.00 ± 0.00 to 0.07 ± 0.06 cm^3 cm^{-3} at MS. Average soil θ_r was higher (not significantly) at DS than MS for both shallow and deeper soil cores.

Soil K_s at DS ranged from 3 to 4 110 cm d^{-1} and from 7 to 2 892 cm d^{-1} in shallow and deeper soil, respectively. At MS, K_s ranged from 431 to 7 762 cm d^{-1} and from 0 to 6 464 cm d^{-1} in shallow and deeper soil, respectively. At both sites and for both depths, values were very variable. Average K_s decreased with depth (not significantly) at each site: from 1 648 ± 791 to 829 ± 600 cm d^{-1} at DS, and from 2 981 ± 1 417 to 2 242 ± 1 248 cm d^{-1} at MS. Average K_s was higher (not significantly) at MS than at DS for both shallow and deeper soil cores.

Soil ϕ at DS ranged from 60 to 69 % and from 60 to 67 % in shallow and deeper soil, respectively. At MS, values ranged from 50 to 59 % in shallow soil and from 46 to 57 % in deeper soil. Average ϕ decreased with depth (not significantly) at each site: from 66 ± 2 to 64 ± 1 % at DS, and from 54 ± 2 to 51 ± 2 % at MS. Average ϕ was higher (not significantly) at DS than MS for both shallow and deeper soil cores.

Soil ε at DS ranged from 18 to 28 % and from 9 to 36 % in shallow and deeper soil, respectively. At MS, values ranged from 9 to 17 % in shallow soil and from 15 to 22 % in deeper soil. Average ε increased with depth (not significantly) at each site: from 22 ± 5 to 24 ± 2 % at DS, and from 14 ± 1 to 19 ± 2 % at MS. Average ε was higher (not significantly) at DS than MS for both shallow and deeper soil cores.

Soil macroporosity at DS ranged from 43 to 53 % in shallow soil and from 28 to 50 % in deeper soil. At MS, values ranged from 40 to 53 % and from 18 to 43 % in shallow and deep soil cores, respectively. Average soil macroporosity significantly decreased with depth at MS (from 45 ± 2 to 35 ± 4 %) but not significantly at DS (from 49 ± 2 to 40 ± 5 %). Average soil macroporosity was higher (not significantly) at DS than MS for both shallow and deeper soil cores.

Soil mesoporosity at DS ranged from 5 to 9 % in shallow soil and from 1 to 6 % in deeper soil. At MS, values ranged from 4 to 8 % and from 0 to 6 %. Average soil mesoporosity were the same at DS and MS for both shallow and deeper soil cores and decreased with depth (not significantly) from 6 ± 3 to 4 ± 2%.

Soil microporosity at DS ranged from 1 to 3 % in both shallow and deeper soil. At MS, values ranged from 1 to 3 % in shallow soil and from 0 to 2 % in deeper soil. Average soil microporosity were the same at DS and MS for both shallow and deeper soil cores and decreased (not significantly) with depth from 2 ± 1 to 1 ± 1%.

Table S6: List and characteristics of rainfall events occurring in 2017

Event	Total rainfall [mm]	Duration [h]	Max rainfall [mm h^{-1}]	Total rainfall 7 days before [mm]	Start	End	Category[a]
1	37.6	40	9.6	0.2	05/01/2017	07/01/2017	D
2	5.6	50	0.8	40	12/01/2017	14/01/2017	A
3	7.6	15	1.6	0.4	23/01/2017	24/01/2017	A
4	35.4	120	3.6	8	26/01/2017	31/01/2017	D
5	10.4	56	2.2	35.4	01/02/2017	03/02/2017	B
(R1) 6	**19**	**29**	**3.2**	**25.4**	**06/02/2017**	**07/02/2017**	B
7	8.6	49	0.8	22.2	12/02/2017	14/02/2017	A
8	15.8	28	2	12.4	17/02/2017	18/02/2017	B
9	5.4	40	2.2	20	21/02/2017	23/02/2017	A
10	8	32	1.8	8	26/02/2017	27/02/2017	A
11	35.2	72	4.2	14	02/03/2017	05/03/2017	D
12	17.6	57	2.4	46.8	06/03/2017	08/03/2017	B
13	6.4	15	2.8	30.4	11/03/2017	12/03/2017	A
14	26	81	4.2	2.4	19/03/2017	22/03/2017	C
15	32	80	5.6	18.6	28/03/2017	31/03/2017	D
16	10.4	24	3.6	1.8	29/04/2017	30/04/2017	B
17	5.2	22	1.4	0.4	13/05/2017	14/05/2017	A
18	24	32	3.6	5.6	14/05/2017	16/05/2017	C
19	8.2	22	1.8	7	26/05/2017	27/05/2017	A
20	12	15	1.8	10	01/06/2017	01/06/2017	B
21	18.6	49	3.4	16	04/06/2017	06/06/2017	B
22	35	43	6.2	33	07/06/2017	08/06/2017	D
(R2) 23	**32.8**	**15**	**6.2**	**55.8**	**09/06/2017**	**10/06/2017**	D
24	17.2	15	4.6	1.2	26/06/2017	27/06/2017	B
25	35.6	18	19.2	0.4	18/07/2017	19/07/2017	D
26	27.8	47	6	36	20/07/2017	22/07/2017	C
27	10	10	4.2	63.4	25/07/2017	26/07/2017	B
28	9.2	30	2	37.8	27/07/2017	28/07/2017	A
29	13.8	39	3	21	01/08/2017	03/08/2017	B
30	7.2	40	1	16.2	06/08/2017	07/08/2017	A
31	14.4	39	2.4	10.4	13/08/2017	15/08/2017	B
32	7.4	12	2.4	16.2	16/08/2017	16/08/2017	A
33	10.6	10	4.4	24	20/08/2017	20/08/2017	B
34	42.2	23	7.4	9	02/09/2017	03/09/2017	E
35	18.4	9	5.2	49.4	04/09/2017	05/09/2017	B
36	7	6	3.8	5.6	12/09/2017	12/09/2017	A
37	22.4	44	4.6	4	19/09/2017	21/09/2017	C
38	7	6	2.4	28	23/09/2017	23/09/2017	A
39	28.4	29	5.6	32.2	26/09/2017	28/09/2017	C
40	14.4	66	2.6	39	28/09/2017	01/10/2017	B
41	10.2	18	2.2	3	10/10/2017	11/10/2017	B
42	37.6	53	6.4	12.8	12/10/2017	14/10/2017	D

43	7.8	16	2.8	53	16/10/2017	16/10/2017	A
(R3) 44	**50.6**	**40**	**6.4**	**57.2**	**18/10/2017**	**19/10/2017**	E
45	16	29	4	70	20/10/2017	21/10/2017	B
46	7.6	13	2.4	74.4	22/10/2017	23/10/2017	A
47	10	21	3.6	74.2	23/10/2017	24/10/2017	B
48	3	14	0.4	83.6	25/10/2017	26/10/2017	A
49	8.4	20	1.6	3.8	19/11/2017	20/11/2017	A
50	29	47	6.2	11.8	21/11/2017	23/11/2017	C
51	13.8	51	2.4	0.6	05/12/2017	07/12/2017	B
52	18.6	31	5.6	15.6	09/12/2017	10/12/2017	B
53	17	62	3.4	34	12/12/2017	14/12/2017	B
54	7.6	16	1.4	12	24/12/2017	25/12/2017	A
55	17.6	15	4.2	18	26/12/2017	26/12/2017	B
56	37	83	5.4	33	28/12/2017	31/12/2017	D

[a] A = 5.0-9.9 mm, B = 10.0-19.9 mm, C = 20.0-29.9 mm, D = 30.0-39.9 mm, E = ≥40 mm