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Transport in a Bare Loam Soil Using Lysimeters and Field Plots

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Abstract: The purpose of this methodological study was to test whether similar soil hydraulic and solute transport properties could be estimated from field plots and lysimeter measurements. The transport of water and bromide (as an inert conservative solute tracer) in three bare field plots and in six bare soil lysimeters were compared. Daily readings of matric head and volumetric water content in the lysimeters showed a profile that was increasingly humid with depth. The hydrodynamic parameters optimized with HYDRUS-1D provided an accurate description of the experimental data for both the field plots and the lysimeters. However, bromide transport in the lysimeters was influenced by preferential transport, which required the use of the mobile/immobile water (MIM) model to suitably describe the experimental data. Water and solute transport observed in the field plots was not accurately described when using parameters optimized with lysimeter data (cross-simulation), and vice versa. The soil's return to atmospheric pressure at the bottom of the lysimeter and differences in tillage practices between the two set-ups had a strong impact on soil water dynamics. The preferential flow of bromide observed in the lysimeters prevented an accurate simulation of solute transport in field plots using the mean optimized parameters on lysimeters and vice versa.

Keywords: field plots; lysimeters; optimization; inverse method; hydrodynamic parameters; cross simulations

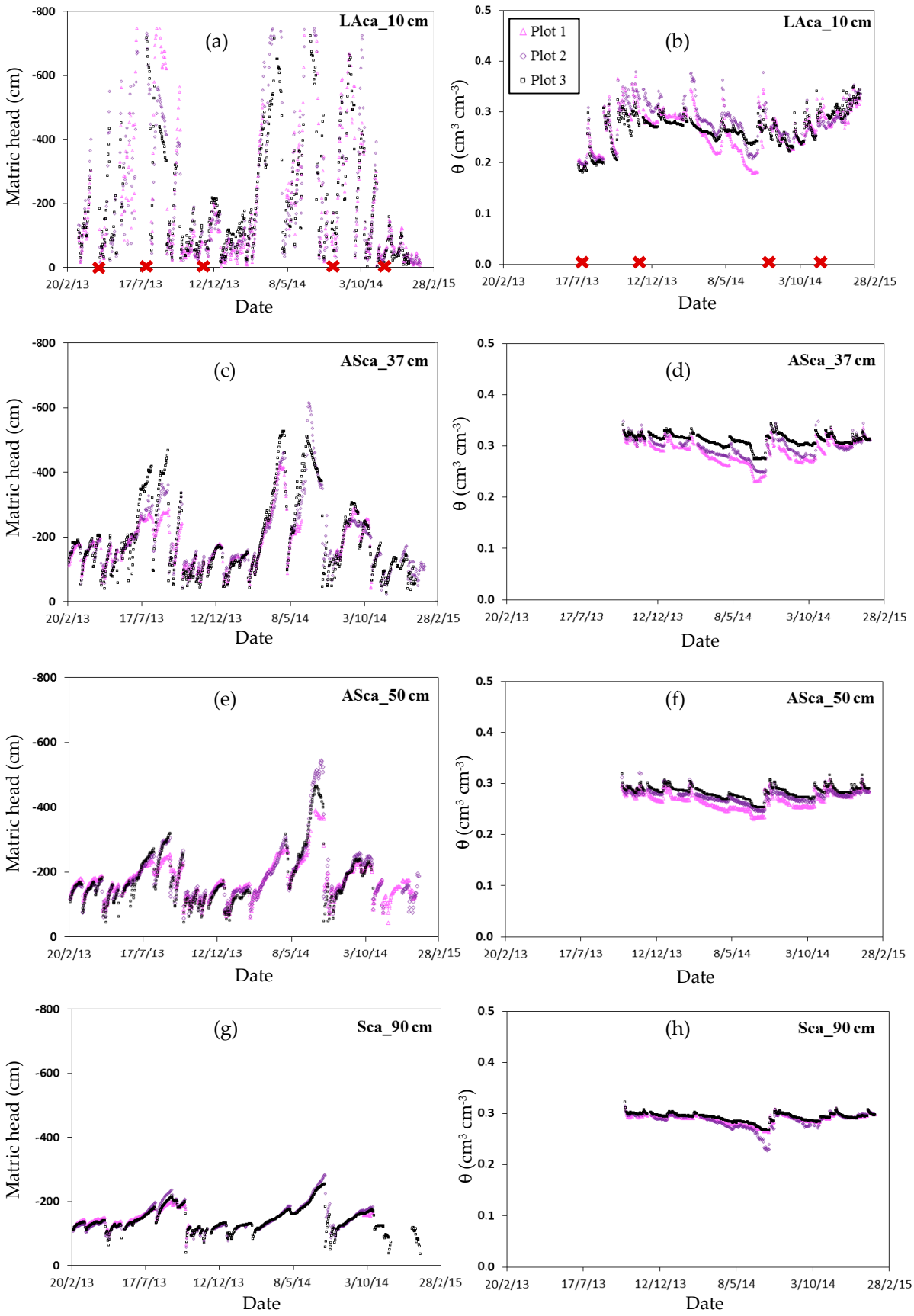

Figure S1. Evolution of daily matric head and volumetric water content data measured at the 10 ((**a**); (**b**)), 37 ((**c**); (**d**)), 50 ((**e**); (**f**)) and 90 ((**g**); (**h**)) cm depths in the three field plots.

Note: The red crosses indicate the dates on which the instruments in the LAca horizon (0–28 cm) were put back in place after tillage.

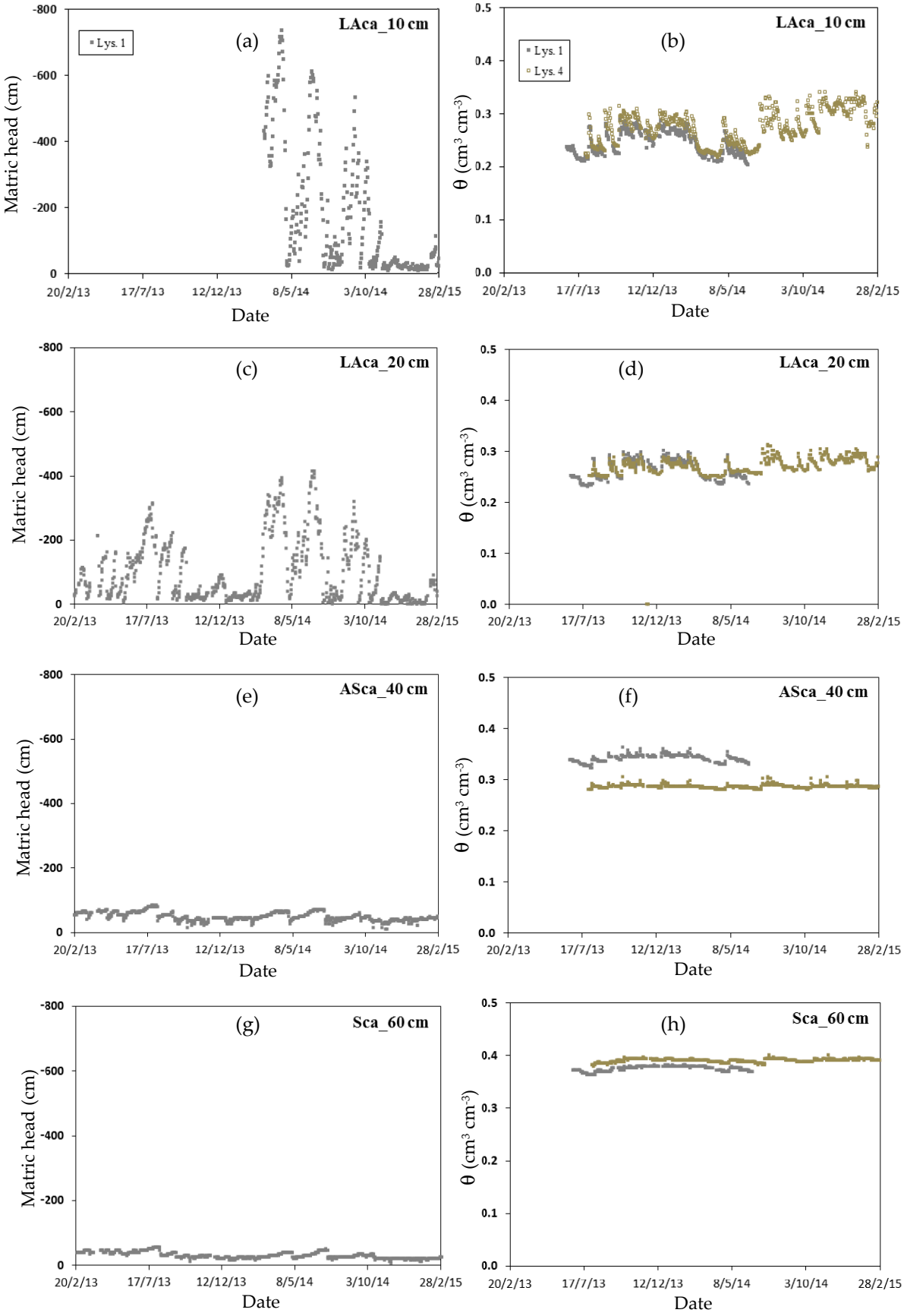

Figure S2. Evolution of daily matric head and water content data measured at the 10 ((**a**); (**b**)), 20 ((**c**); (**d**)), 40 ((**e**); (**f**)) and 60 ((**g**); (**h**)) cm depths in Lys. 1 and 4.

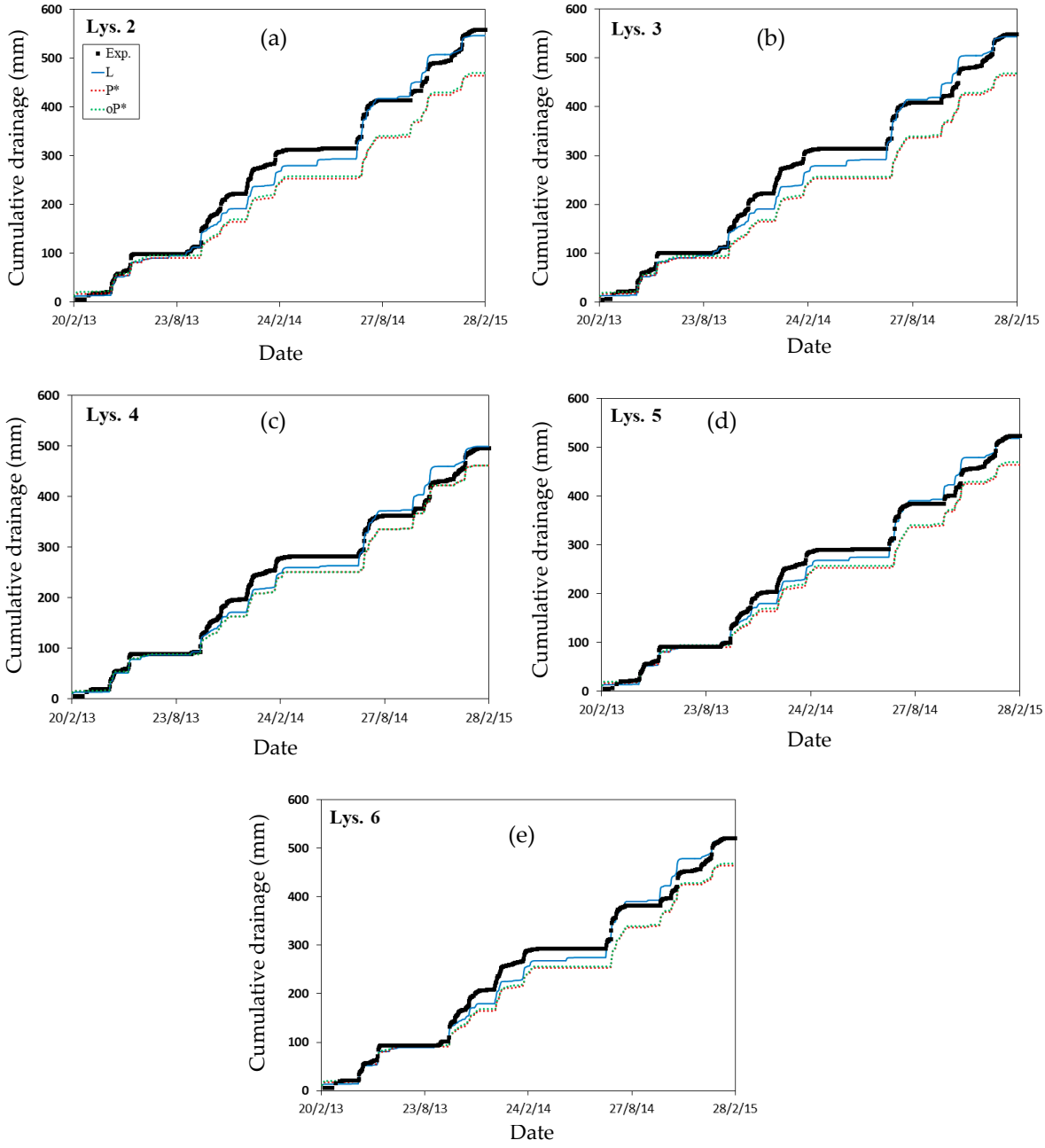

Figure S3. Comparison between experimental and simulated drainage on Lys. 2 (**a**), 3 (**b**), 4 (**c**), 5 (**d**) and 6 (**e**).

Note: L for results obtained with optimized parameters with HYDRUS-1D on lysimeter data; P* for results obtained by applying the mean optimized parameters from the 165 cm deep profile of the three field plots; oP*, the same as P* but for saturated water content values (θ_s*) again optimized for each soil material.

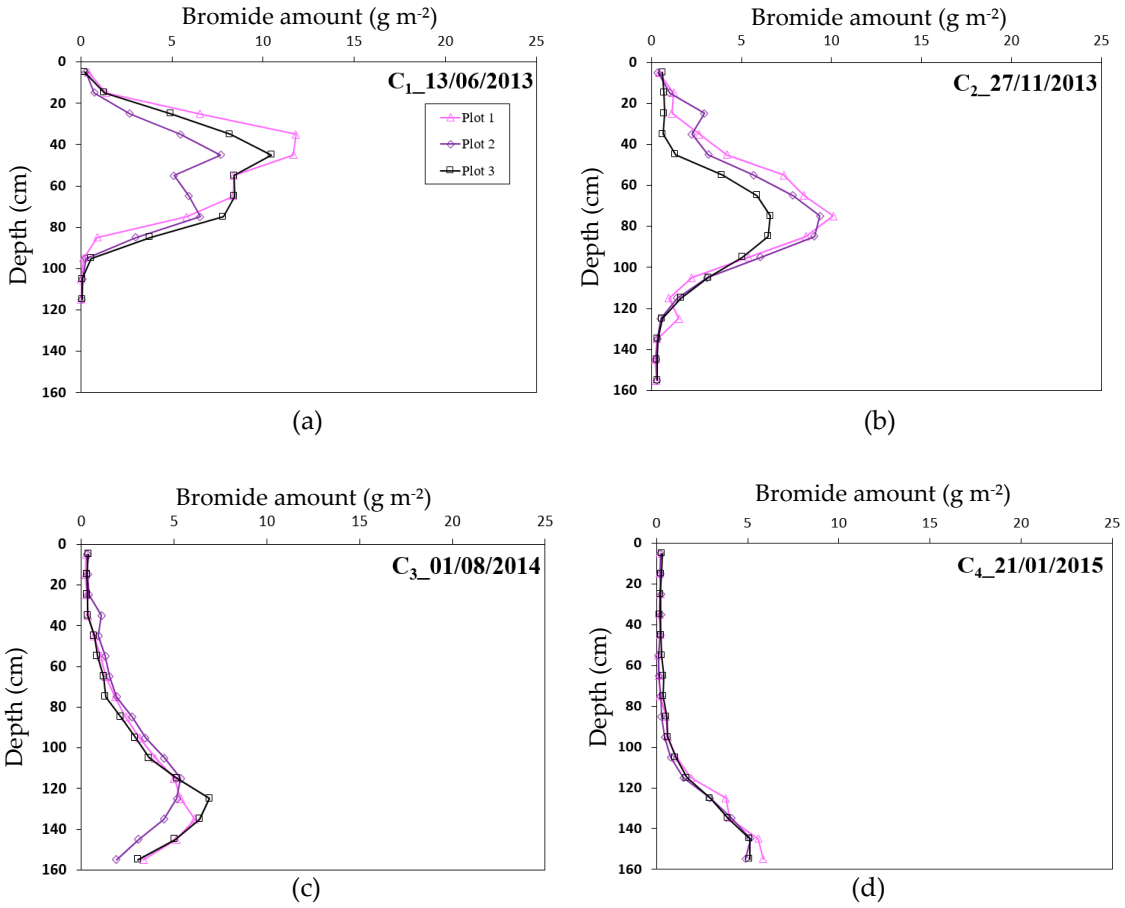

***Figure* S4.** The average bromide concentration profiles obtained for each of the four monitoring campaigns (C_1 (**a**), C_2 (**b**), C_3 (**c**), and C_4 (**d**)).

Note: To facilitate comparison of the results obtained on each field plot, the standard deviations are not shown on the curves. Due to problems with the Geonor sampler for C_4 on Plot 1, only data obtained from the samples taken with the auger were accounted for.

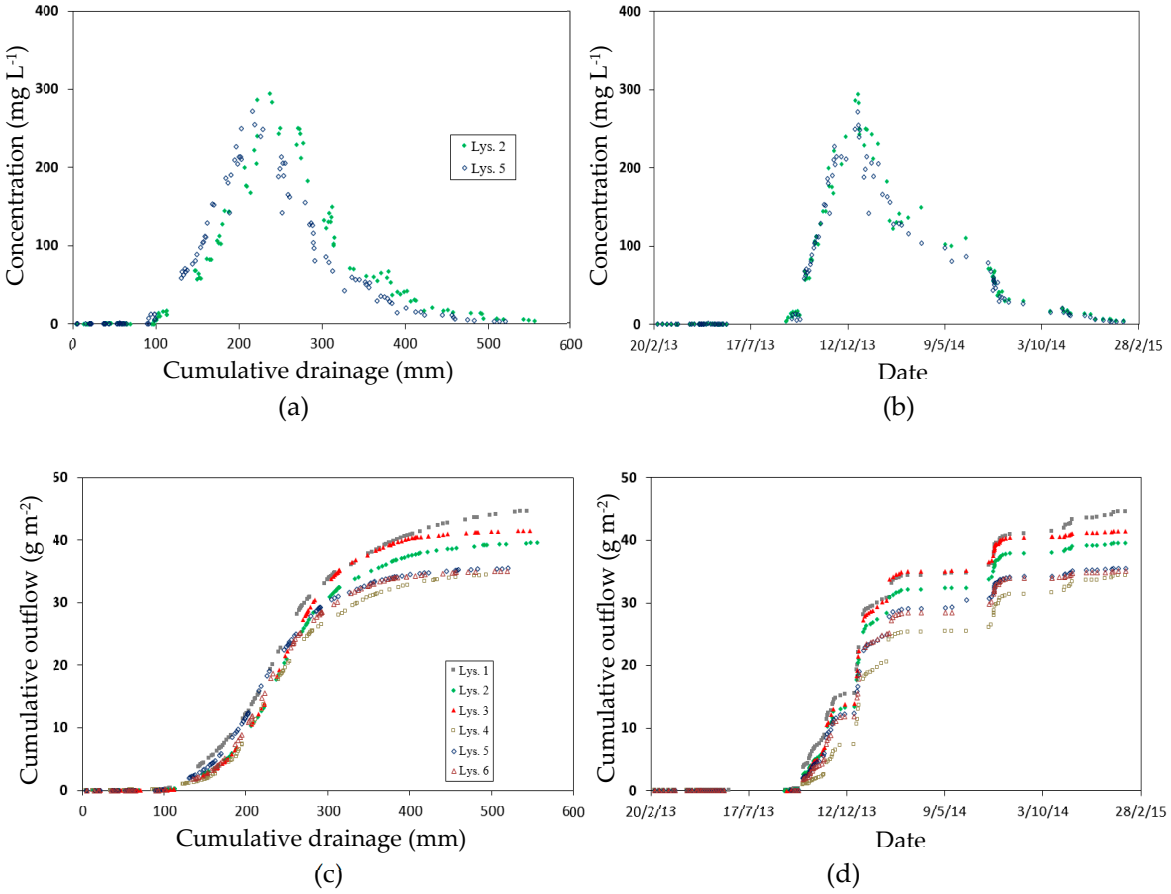

Figure S5. Bromide concentration (Lys. 2 and 5) and cumulative outflow (all lysimeters), as a function of cumulative drainage ((**a**); (**c**)) and time ((**b**); (**d**)).

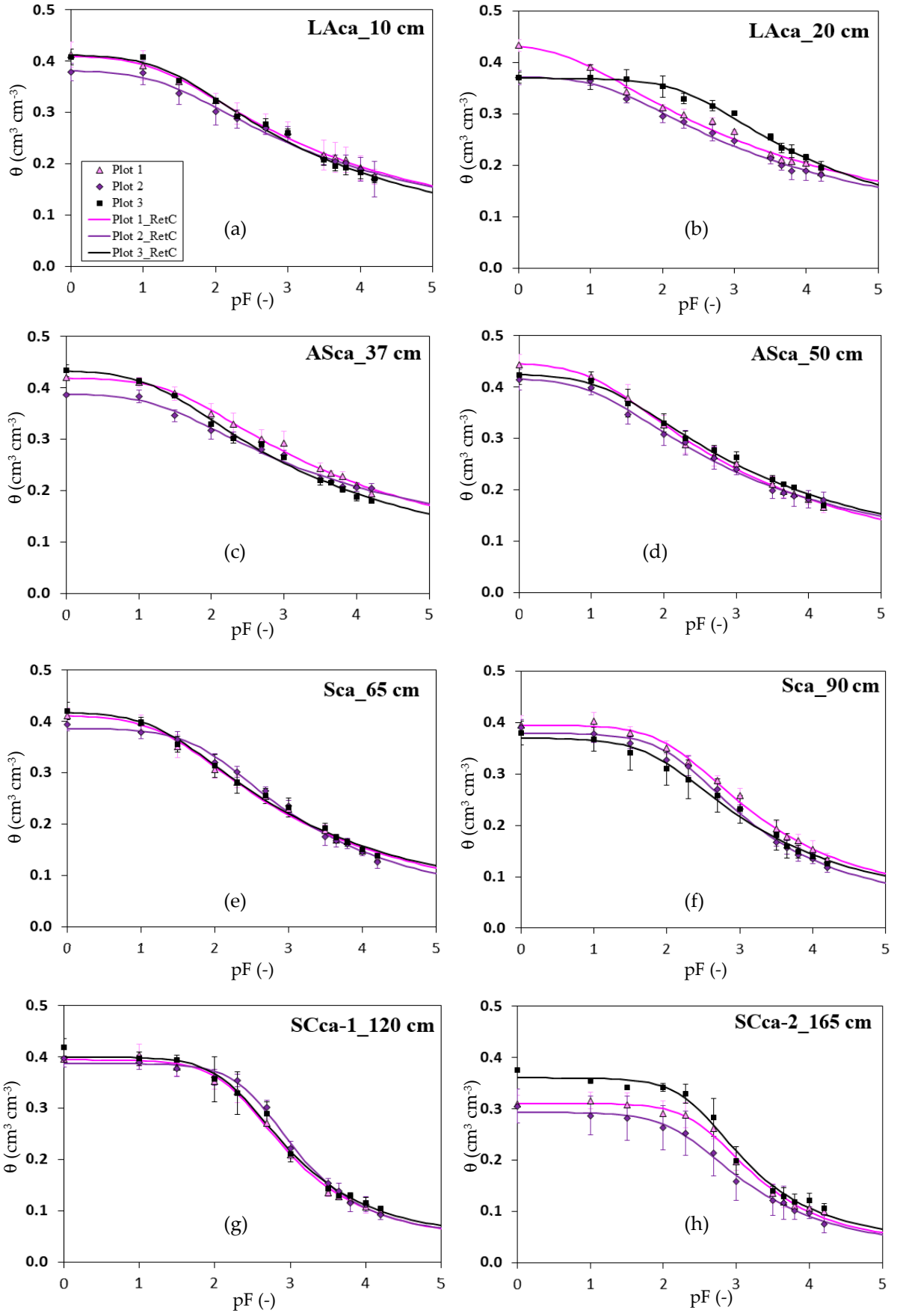

Figure S6. Comparison between experimental (obtained in the laboratory) and fitted (with RetC) water retention curves at the 10 (**a**), 20 (**b**), 37 (**c**), 50 (**d**), 65 (**e**), 90 (**f**), 120 (**g**) and 165 (**h**) cm depths on the three field plots.

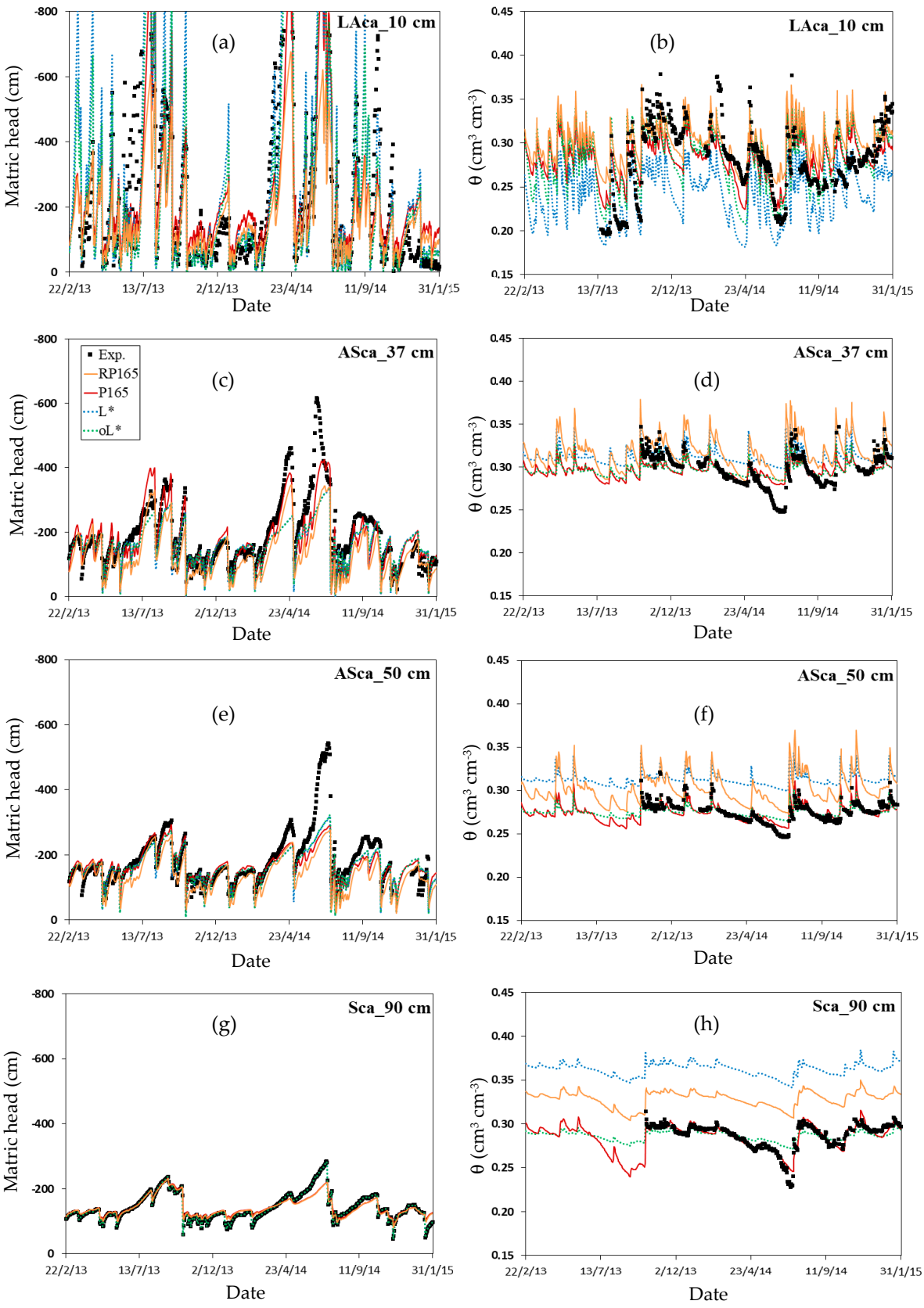

Figure S7. Comparison of experimental and simulated matric head and volumetric water content data at the 10 ((**a**); (**b**)), 37 ((**c**); (**d**)), 50 ((**e**); (**f**)) and 90 ((**g**); (**h**)) cm depths on Field Plot 2.

Note: RP165 for results obtained with the parameters optimized with RetC, P165 for results obtained with the parameters optimized with HYDRUS-1D on the 165 cm deep profile; P90 for results obtained by applying the parameters optimized for the 165 cm deep profile to the 90 cm deep profile; L* for results obtained by applying the mean optimized parameters from the six lysimeters; oL*, the same as L* but for saturated water content values (θ_s*) again optimized for each soil material.

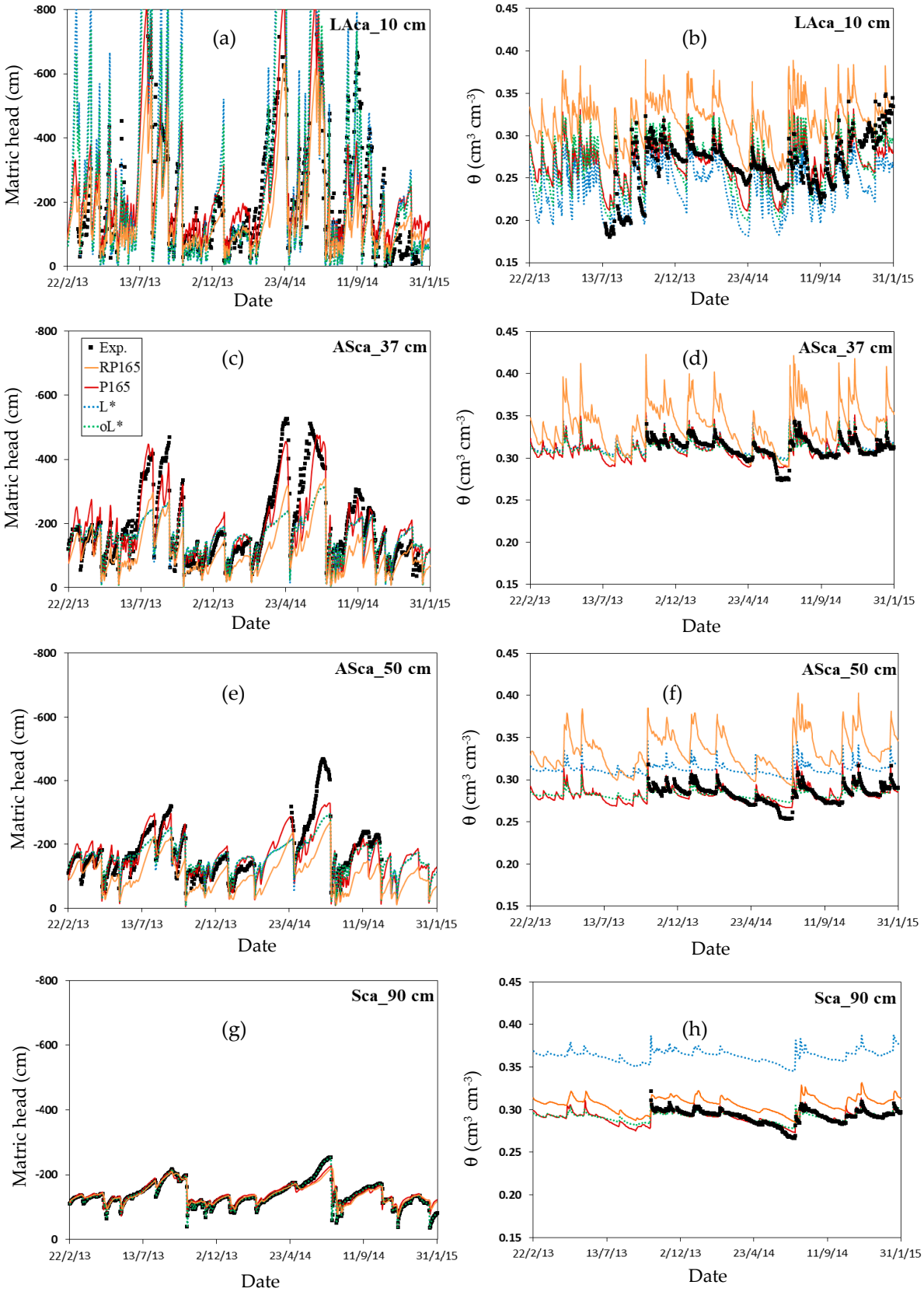

Figure S7 (continued). Comparison of experimental and simulated matric head and volumetric water content data at the 10 ((**a**); (**b**)), 37 ((**c**); (**d**)), 50 ((**e**); (**f**)) and 90 ((**g**); (**h**)) cm depths on Field Plot 3.

Note: RP165 for results obtained with the parameters optimized with RetC, P165 for results obtained with the parameters optimized with HYDRUS-1D on the 165 cm deep profile; P90 for results obtained by applying the parameters optimized for the 165 cm deep profile to the 90 cm deep profile; L* for results obtained by applying the mean optimized parameters from the six lysimeters; oL*, the same as L* but for saturated water content values (θ_s*) again optimized for each soil material.

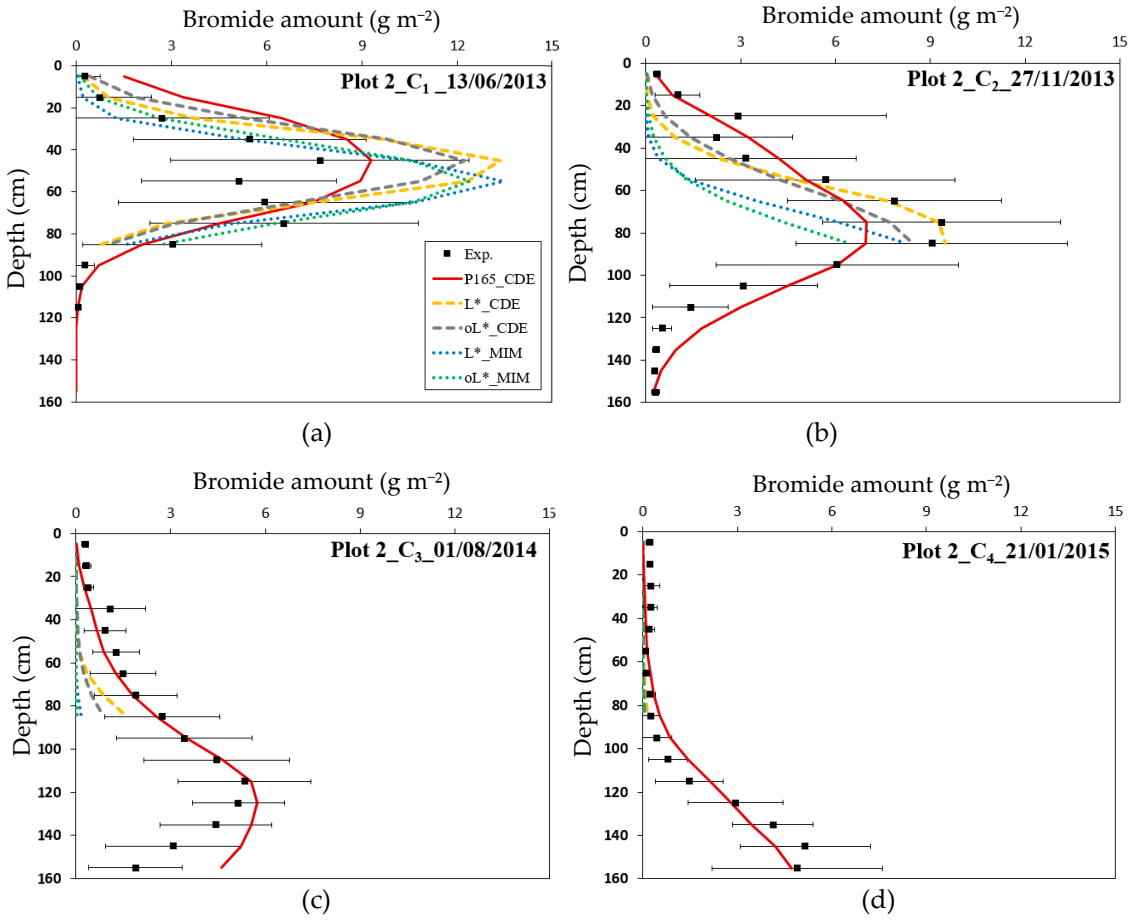

Figure S8. Comparison between experimental and simulated bromide concentrations in Field Plot 2 for the four monitoring campaigns (C_1 (**a**), C_2 (**b**), C_3 (**c**), and C_4 (**d**)).

Note: Each experimental point is the average of 8 to 11 samples and is accompanied by its standard deviation. P165_CDE for results obtained with HYDRUS-1D with the convection-dispersion equation and parameters optimized on the 165 cm deep profile; L*_CDE for the results obtained with the convection-dispersion equation and by applying the mean optimized parameters from the six lysimeters; L*_MIM for the results obtained with the mobile-immobile model and by applying the mean optimized parameters from the six lysimeters; oL*, the same as L* but for saturated water content values (θ_s*) again optimized for each soil material. Results obtained with the convection-dispersion equation and parameters optimized on the 90 cm deep profile are not shown since no significant differences were found with P165_CDE for simulated bromide amount.

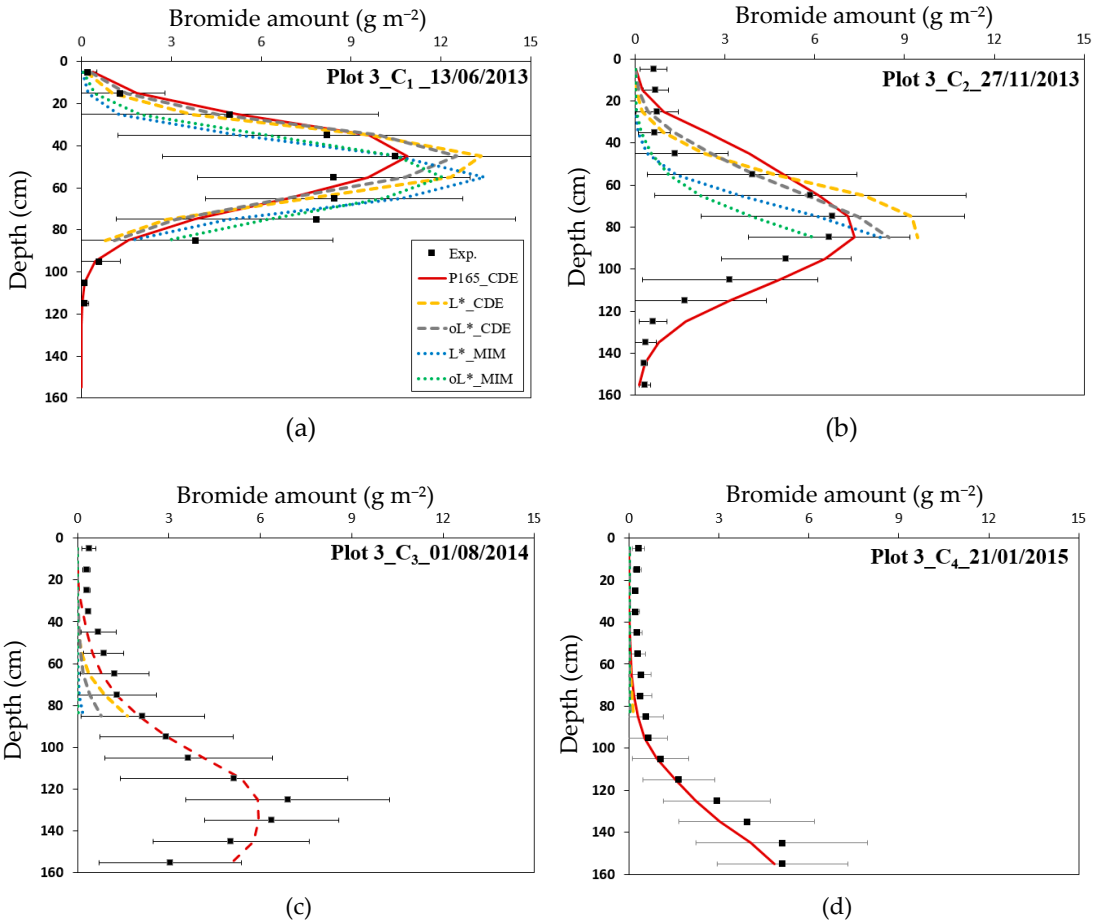

Figure S8 (continued). Comparison between experimental and simulated bromide concentrations in Field Plot 3 for the four monitoring campaigns (C_1 (**a**), C_2 (**b**), C_3 (**c**), and C_4 (**d**)).

Note: Each experimental point is the average of 8 to 11 samples and is accompanied by its standard deviation. P165_CDE for results obtained with HYDRUS-1D with the convection-dispersion equation and parameters optimized on the 165 cm deep profile; L*_CDE for the results obtained with the convection-dispersion equation and by applying the mean optimized parameters from the six lysimeters; L*_MIM for the results obtained with the mobile-immobile model and by applying the mean optimized parameters from the six lysimeters; oL*, the same as L* but for saturated water content values (θ_s*) again optimized for each soil material. Results obtained with the convection-dispersion equation and parameters optimized on the 90 cm deep profile are not shown since no significant differences were found with P165_CDE for simulated bromide amount.

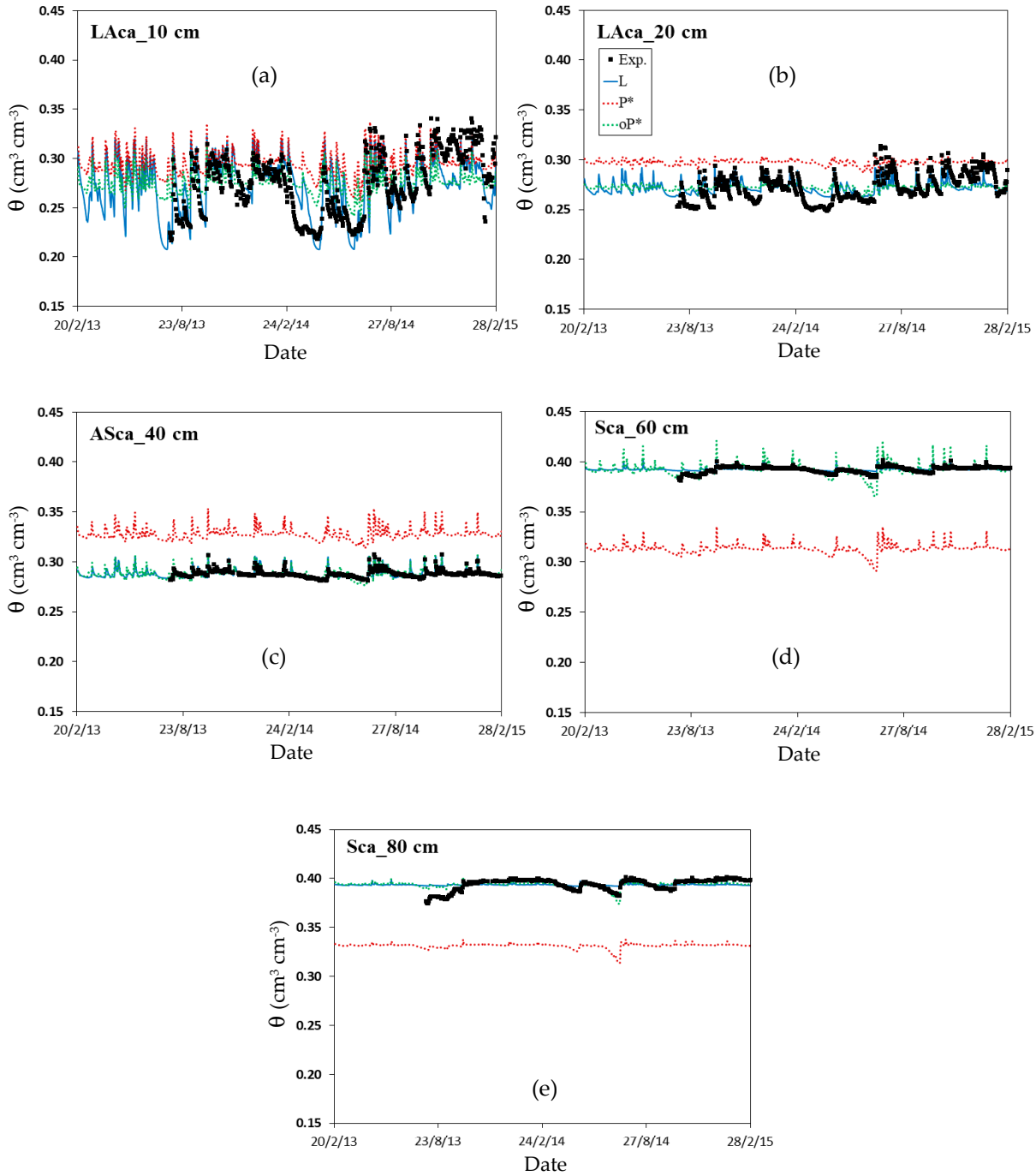

Figure S9. Comparison between experimental and simulated volumetric water content data at the 10 (**a**), 20 (**b**), 40 (**c**), 60 (**d**) and 80 (**e**) cm depths on Lys. 4.

Note: L for results obtained with the parameters optimized with HYDRUS-1D on lysimeter data; P* for results obtained by applying the mean optimized parameters from the 165 cm deep profile of the three field plots; oP*, the same as P* but for saturated water content values (θ_s*) again optimized for each soil material.

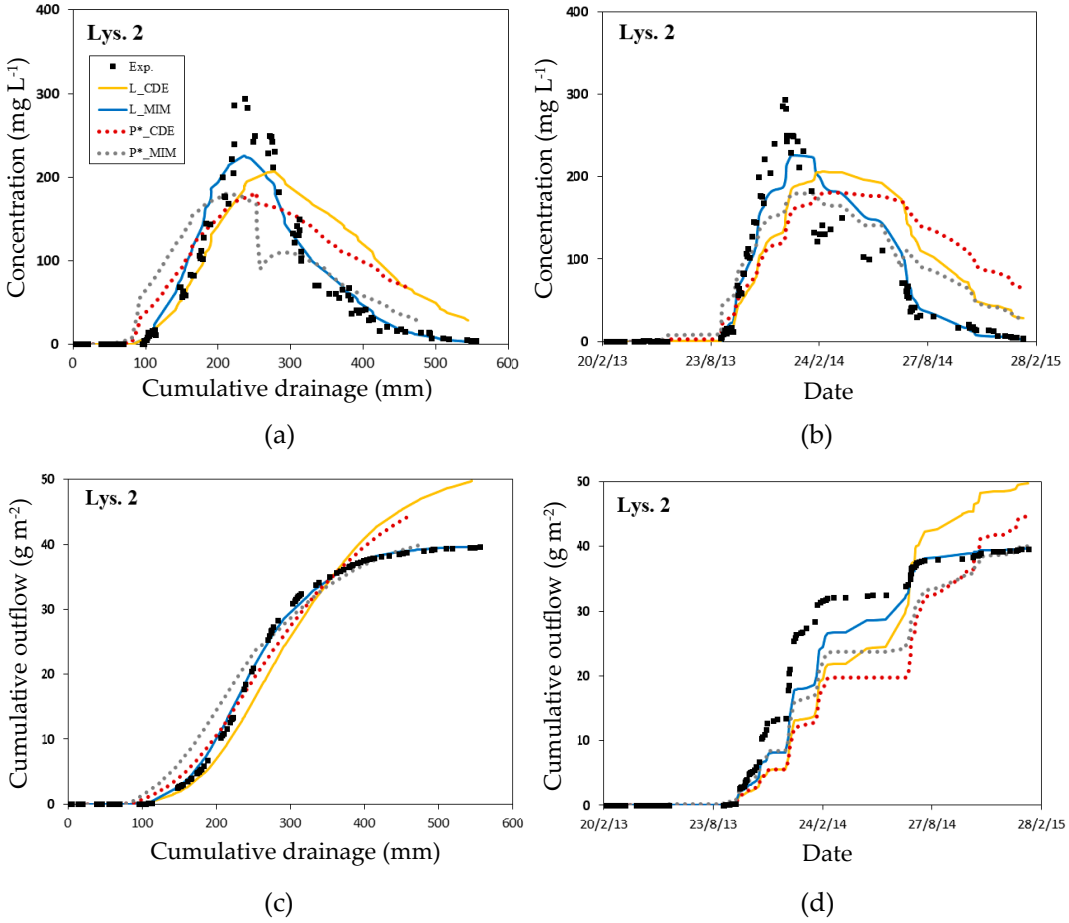

Figure S10. Comparison between experimental and simulated bromide concentration and cumulative outflow as a function of cumulative drainage ((**a**); (**c**)) and time ((**b**); (**d**)) on Lys. 2.

Note: L_CDE for results obtained with the convection-dispersion equation and parameters optimized with HYDRUS-1D on lysimeter data; L_MIM for results obtained with the mobile-immobile model and parameters optimized with HYDRUS-1D on lysimeter data; P*_CDE for results obtained with the convection-dispersion equation and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots; P*_MIM for the results obtained with the mobile-immobile model and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots. Results obtained with oP* are not shown since the bromide concentration dynamics found as a function of cumulative drainage and time were similar to P*.

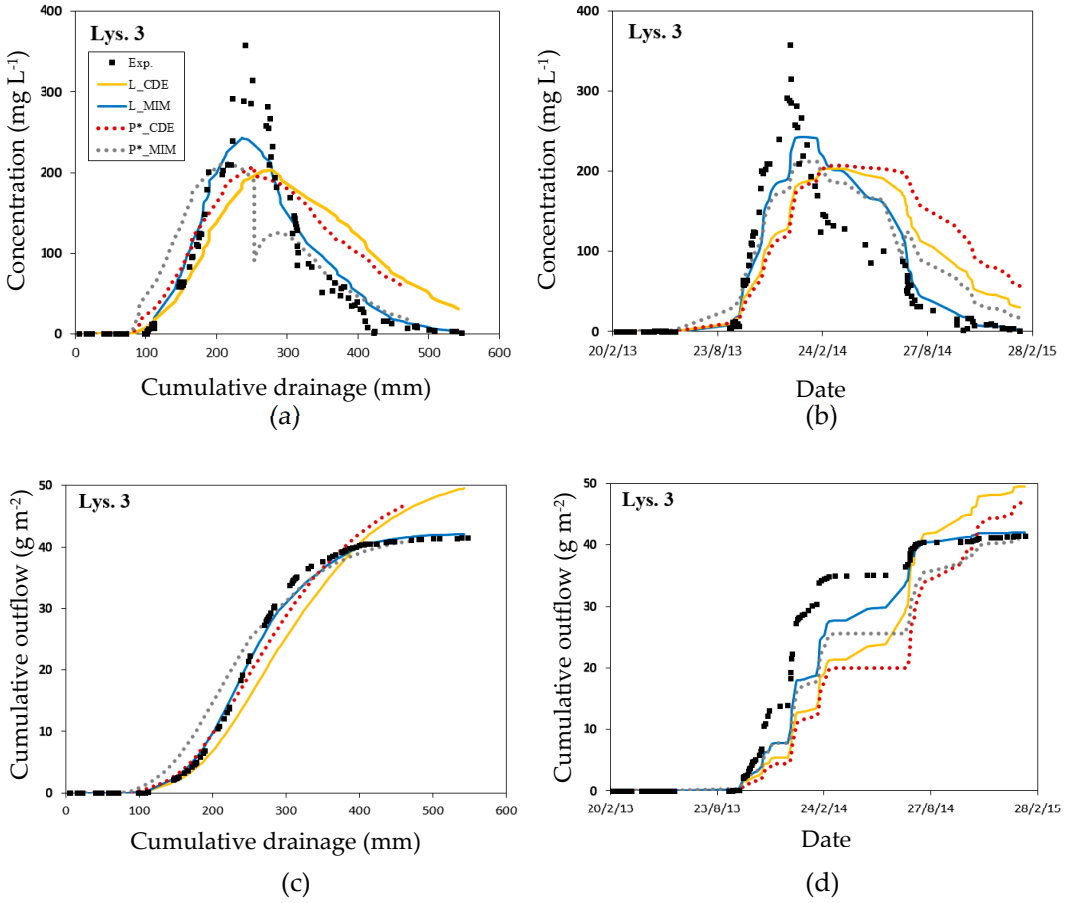

Figure S10 (continued). Comparison between experimental and simulated bromide concentration and cumulative outflow as a function of cumulative drainage ((**a**); (**c**)) and time ((**b**); (**d**)) on Lys. 3.

Note: L_CDE for results obtained with the convection-dispersion equation and parameters optimized with HYDRUS-1D on lysimeter data; L_MIM for results obtained with the mobile-immobile model and parameters optimized with HYDRUS-1D on lysimeter data; P*_CDE for results obtained with the convection-dispersion equation and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots; P*_MIM for the results obtained with the mobile-immobile model and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots. Results obtained with oP* are not shown since the bromide concentration dynamics found as a function of cumulative drainage and time were similar to P*.

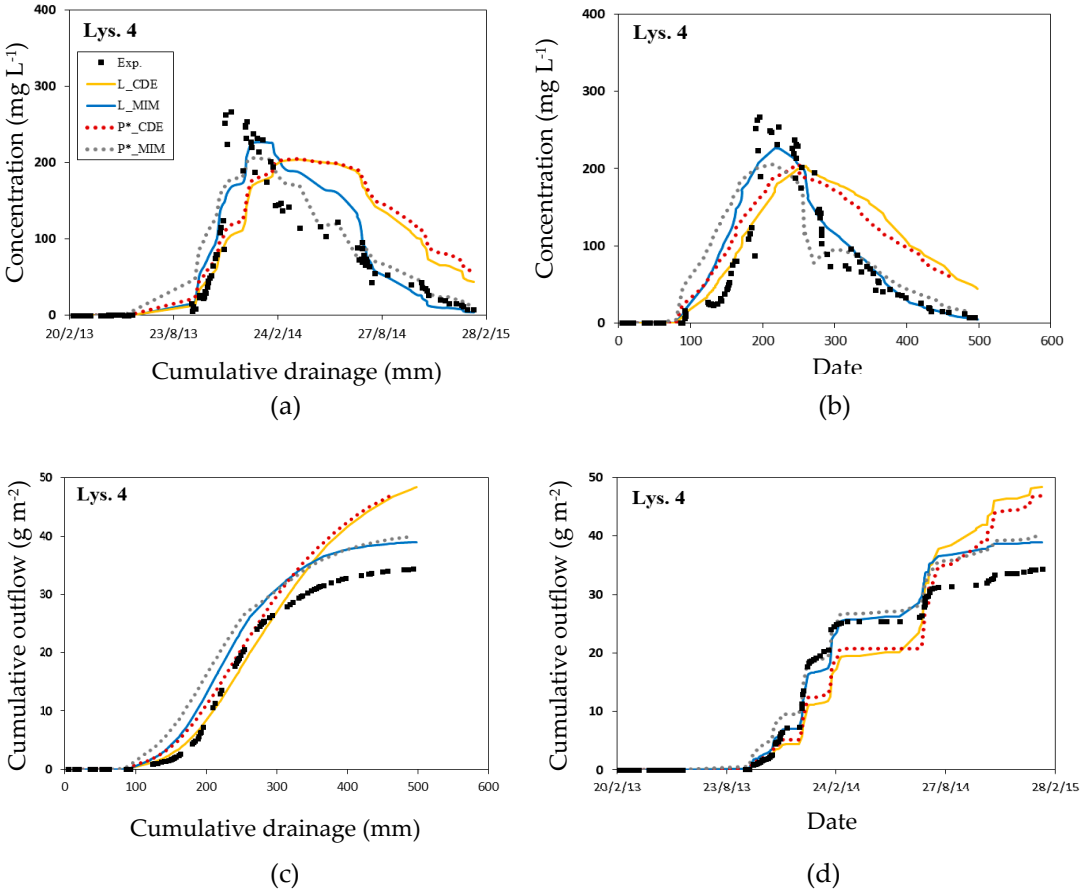

Figure S10 (continued). Comparison between experimental and simulated bromide concentration and cumulative outflow as a function of cumulative drainage ((**a**); (**c**)) and time ((**b**); (**d**)) on Lys. 4.

Note: L_CDE for results obtained with the convection-dispersion equation and parameters optimized with HYDRUS-1D on lysimeter data; L_MIM for results obtained with the mobile-immobile model and parameters optimized with HYDRUS-1D on lysimeter data; P*_CDE for results obtained with the convection-dispersion equation and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots; P*_MIM for the results obtained with the mobile-immobile model and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots. Results obtained with oP* are not shown since the bromide concentration dynamics found as a function of cumulative drainage and time were similar to P*.

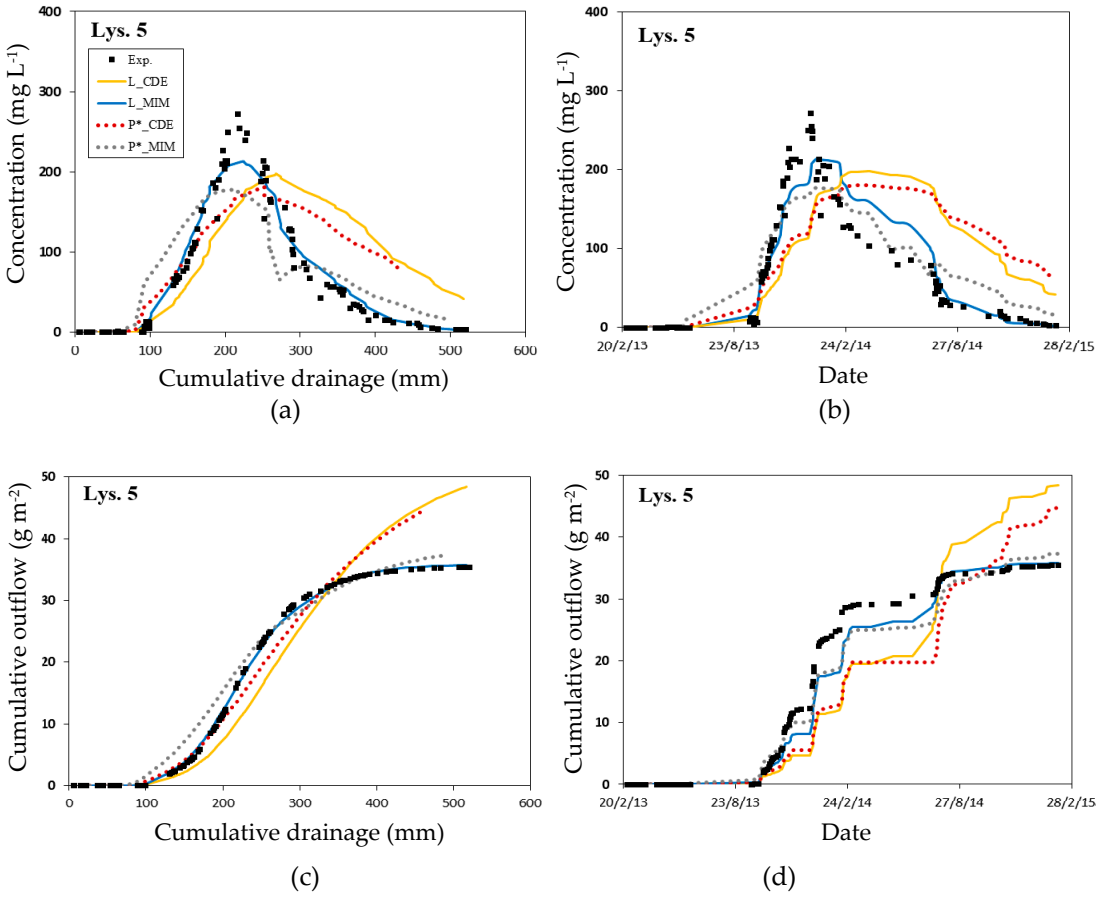

Figure S10 (continued). Comparison between experimental and simulated bromide concentration and cumulative outflow as a function of cumulative drainage ((**a**); (**c**)) and time ((**b**); (**d**)) on Lys. 5. Note: L_CDE for results obtained with the convection-dispersion equation and parameters optimized with HYDRUS-1D on lysimeter data; L_MIM for results obtained with the mobile-immobile model and parameters optimized with HYDRUS-1D on lysimeter data; P*_CDE for results obtained with the convection-dispersion equation and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots; P*_MIM for the results obtained with the mobile-immobile model and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots. Results obtained with oP* are not shown since the bromide concentration dynamics found as a function of cumulative drainage and time were similar to P*.

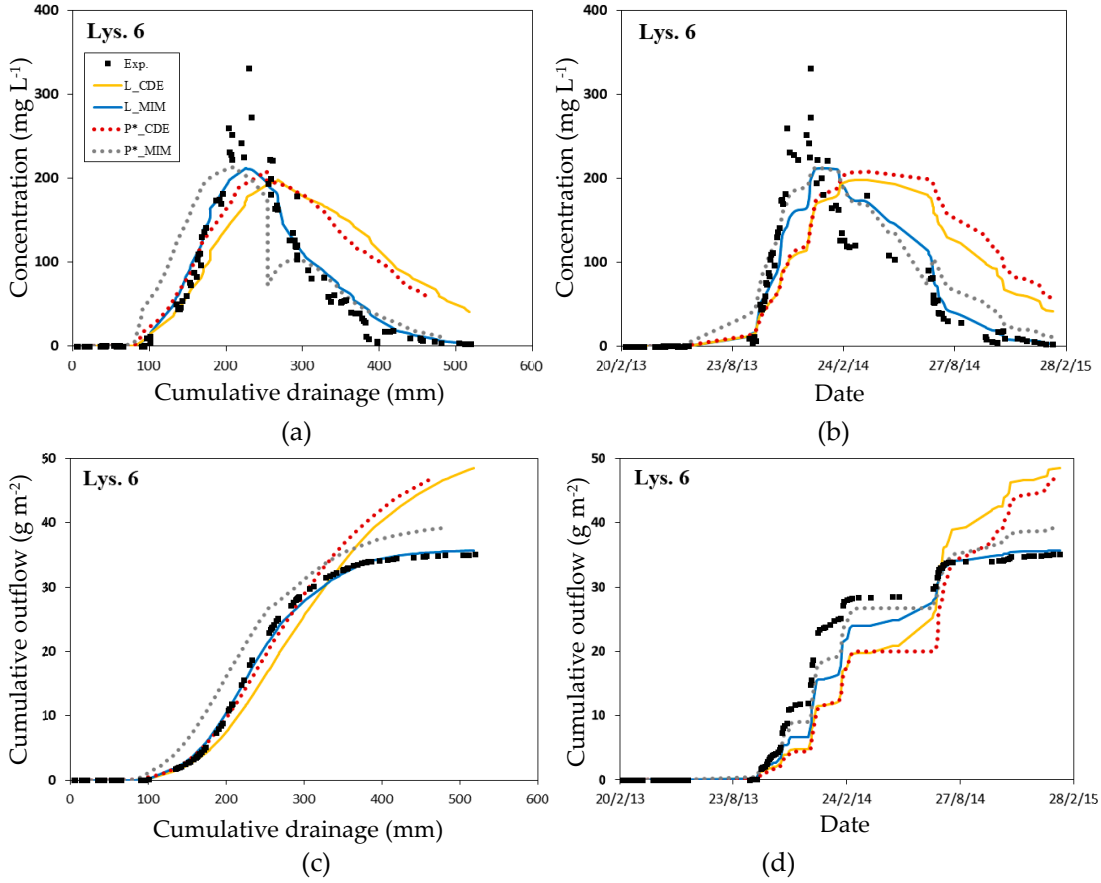

Figure S10 (continued). Comparison between experimental and simulated bromide concentration and cumulative outflow as a function of cumulative drainage ((**a**); (**c**)) and time ((**b**); (**d**)) on Lys. 6.

Note: L_CDE for results obtained with the convection-dispersion equation and parameters optimized with HYDRUS-1D on lysimeter data; L_MIM for results obtained with the mobile-immobile model and parameters optimized with HYDRUS-1D on lysimeter data; P*_CDE for results obtained with the convection-dispersion equation and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots; P*_MIM for the results obtained with the mobile-immobile model and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots. Results obtained with oP* are not shown since the bromide concentration dynamics found as a function of cumulative drainage and time were similar to P*.

Table S1. Particle size fractions (in %) of the eight soil materials of the three field plots.

Soil Material	Field Plot 1			Field Plot 2			Field Plot 3		
	Clay	**Silt**	**Sand**	**Clay**	**Silt**	**Sand**	**Clay**	**Silt**	**Sand**
M_{1p}	21.4 (0.5)	70.3 (1.2)	8.3 (1.3)	25.3 (0.5)	65.9 (1.2)	8.7 (0.6)	17.0 (0.4)	74.1 (0.9)	8.9 (0.6)
M_{2p}	20.9 (0.8)	71.3 (0.9)	7.9 (0.6)	25.8 (0.2)	65.5 (0.3)	8.8 (0.4)	17.4 (0.6)	74.0 (0.9)	8.6 (0.6)
M_{3p}	19.0 (1.7)	73.8 (3.1)	7.2 (1.4)	25.5 (1)	68.7 (1.5)	5.8 (0.4)	22.3 (1.8)	72.1 (2.4)	5.7 (0.6)
M_{4p}	17.3 (0.3)	76.5 (1.2)	6.2 (0.9)	23.5 (1.8)	71.0 (1.8)	5.6 (0.3)	23.1 (1.8)	71.4 (2.7)	5.5 (0.5)
M_{5p}	16.8 (0.4)	76.2 (1.7)	6.9 (1.0)	21.1 (0.9)	72.4 (1.8)	6.5 (1)	20.5 (2.5)	71.5 (4)	7.9 (5.5)
M_{6p}	15.7 (1.5)	78.4 (5.7)	5.9 (1.7)	15.9 (2.8)	78.2 (4.6)	6.0 (1.8)	18.3 (1.3)	75.2 (6.2)	6.5 (5.3)
M_{7p}	13.4 (0.4)	81.3 (1.7)	5.2 (1.7)	13.0 (0.5)	81.3 (2.7)	5.7 (2.8)	17.7 (1.4)	75.6 (4.1)	6.8 (3.2)
M_{8p}	10.6 (5.6)	66.8 (14)	22.7 (18.2)	8.7 (4.1)	50.5 (21.8)	40.8 (26.9)	13.5 (0.9)	64.2 (6.1)	22.2 (6.9)

Note: Three samples were taken every 10 cm from 0 to 170 cm depth in each field plot. Means were calculated from the three values obtained at all depths included in those defining the soil material. Standard deviations are given in parentheses.

Table S2. Bulk density and saturated hydraulic conductivity mean values obtained at each instrumented depth in each field plot.

Depth. (cm)	ρ_b **(g cm^{-3})**	K_s **(cm d^{-1})**
10	1.32 (0.11)	110.2 (78.2)
20	1.38 (0.12)	575.2 (245.0)
37	1.33 (0.08)	71.0 (37.2)
50	1.22 (0.05)	76.9 (18.4)
65	1.28 (0.06)	29.1 (8.4)
90	1.41 (0.08)	16.7 (6.3)
120	1.45 (0.07)	16.1 (4.0)
165	1.57 (0.09)	19.8 (13.3)

Note: For K_s, three samples were taken at each instrumented depth of Field Plot 3. For ρ_b, six samples were taken below the surface layer (LAca) during instrumentation and 25 were taken at 10 and 20 cm depth at different times of the year and for different soil structural state. Standard deviations are given in parentheses.

Table S3. Parameters optimized using HYDRUS-1D for each of the eight soil materials of Field Plot 2.

Soil Material	θ_r (cm³ cm⁻³)	θ_s (cm³ cm⁻³)	α (cm⁻¹)	n (-)	K_s (cm d⁻¹)	λ (cm)	θ_s* (cm³ cm⁻³)
M_{1P}	0.062 (0.075) [0.062–0.108]	**0.355** (0.382) [0.350–0.360]	0.019 (0.047) [0.018–0.020]	**1.199** (1.160) [1.187–1.210]	41.8 [37.0–46.7]	3.0	0.342 [0.340–0.344]
M_{2P}	0.079 (0.085) [0.077–0.097]	**0.393** (0.373) [0.378–0.409]	0.022 (0.050) [0.014–0.031]	**1.211** (1.163) [1.187–1.233]	*575.2*	3.0	0.344 [0.341–0.347]
M_{3P}	0.109 (0.103) [0.095–0.109]	**0.333** (0.389) [0.325–0.341]	0.031 (0.044) [0.028–0.034]	**1.103** (1.165) [1.087–1.119]	*69.7*	6.0	0.334 [0.332–0.336]
M_{4P}	0.082 (0.086) [0.082–0.095]	**0.352** (0.418) [0.349–0.355]	0.037 (0.073) [0.035–0.039]	1.179 (1.187) [1.146–1.212]	73.9 [58.6–89.1]	6.0	0.309 [0.307–0.311]
M_{5P}	0.044 (0.049) [0.044–0.054]	0.392 (0.387) [0.385–0.399]	0.012 (0.013) [0.012–0.012]	**1.437** (1.254) [1.374–1.504]	**16.5** [16.2–16.8]	2.5	0.313 [0.311–0.315]
M_{6P}	0.044 (0.046) [0.043–0.051]	**0.352** (0.379) [0.347–0.357]	0.006 (0.007) [0.006–0.007]	**1.781** (1.315) [1.673–1.889]	*16.7*	2.5	0.313 [0.311–0.315]
M_{7P}	0.049 (0.050) [0.049–0.053]	**0.349** (0.387) [0.343–0.356]	0.002 (0.003) [0.002–0.003]	*1.547* (1.547)	*16.1*	4.0	/
M_{8P}	0.036 (0.027) [0.024–0.036]	**0.374** (0.293) [0.369–0.379]	0.005 (0.005) [0.004–0.006]	*1.365* (1.365)	*19.8*	4.0	/

Note: Initial values obtained with RetC from laboratory water retention measurements are given in parentheses after the optimized value. Confidence intervals associated with parameters optimized using HYDRUS-1D are given in brackets. Parameters θ_r, θ_s, α, n and K_s optimized using HYDRUS-1D are highlighted: (i) in **bold** for parameters whose **optimized value is not included in the initial bounds**, (ii) in *italics* for non-optimized parameters *set to the mean initial value*. Saturated water content values re-optimized during the cross-simulations are noted θ_s*. The soil dispersivity (λ) was set manually for each individual soil material.

Table S3 (continued). Parameters optimized using HYDRUS-1D for each of the eight soil materials of Field Plot 3.

Soil Material.	θ_r (cm³ cm⁻³)	θ_s (cm³ cm⁻³)	α (cm⁻¹)	n (-)	K_s (cm d⁻¹)	λ (cm)	θ_s* (cm³ cm⁻³)
M_{1p}	0.065 (0.068) [0.065–0.070]	**0.347** (0.413) [0.343–0.351]	**0.018** (0.042) [0.018–0.019]	**1.239** (1.181) [1.227–1.250]	**26.8** [17.2–35.9]	1.0	0.327 [0.325–0.328]
M_{2p}	0.069 (0.073) [0.069–0.080]	**0.304** (0.369) [0.302–0.306]	0.002 (0.004) [0.002–0.003]	**1.317** (1.202) [1.226–1.409]	*575.2*	1.0	0.318 [0.317–0.320]
M_{3p}	0.077 (0.074) [0.071–0.077]	**0.362** (0.435) [0.360–0.364]	0.058 (0.055) [0.054–0.061]	**1.089** (1.174) [1.080–1.099]	**508.6** [407.9–609.3]	3.0	0.350 [0.349–0.352]
M_{4p}	0.070 (0.072) [0.070–0.075]	**0.332** (0.426) [0.330–0.334]	0.046 (0.054) [0.042–0.049]	**1.103** (1.172) [1.088–1.118]	**147.3** [105.0–189.7]	3.0	0.318 [0.316–0.319]
M_{5p}	0.052 (0.054) [0.052–0.058]	**0.340** (0.419) [0.334–0.345]	**0.018** (0.045) [0.016–0.020]	1.224 (1.206) [1.187–1.260]	29.0 [10.7–46.9]	2.0	0.303 [0.301–0.304]
M_{6p}	0.043 (0.047) [0.043–0.052]	**0.340** (0.370) [0.334–0.346]	0.011 (0.012) [0.009–0.012]	1.226 (1.251) [1.187–1.265]	*16.7*	2.0	0.318 [0.317–0.320]
M_{7p}	0.041 (0.048) [0.041–0.053]	**0.349** (0.400) [0.343–0.355]	**0.002** (0.005) [0.002–0.002]	*1.439* (1.439)	*16.1*	2.0	/
M_{8p}	0.041 (0.045) [0.041–0.053]	**0.391** (0.361) [0.376–0.407]	**0.006** (0.003) [0.003–0.010]	1.524 (1.471) [1.118–1.931]	*19.8*	2.0	/

Note: Initial values obtained with RetC from laboratory water retention measurements are given in parentheses after the optimized value. Confidence intervals associated with parameters optimized using HYDRUS-1D are given in brackets. Parameters θ_r, θ_s, α, n and K_s optimized using HYDRUS-1D are highlighted: (i) in **bold** for parameters whose **optimized value is not included in the initial bounds**, (ii) in *italics* for non-optimized parameters *set to the mean initial value*. Saturated water content values re-optimized during the cross-simulations are noted θ_s*. The soil dispersivity (λ) was set manually for each individual soil material.

Table S4. Efficiency coefficients calculated at each instrumented depth in Field Plots 2 and 3 and based on different optimization procedures using HYDRUS-1D.

Field Plot 2	**M_{1p}_10**	**M_{2p}_20**	**M_{3p}_37**	**M_{4p}_50**	**M_{5p}_65**	**M_{6p}_90**	**M_{7p}_120**	**M_{8p}_165**
h_RP165	0.44	0.51	0.39	0.38	0.78	0.84	0.85	*1.00*
h_P165	0.53	0.65	0.69	0.57	0.74	0.83	0.85	*1.00*
h_P90	0.52	0.66	0.72	0.73	0.88	*1.00*	/	/
h_L*	0.46	0.64	0.52	0.60	0.84	*1.00*	/	/
h_oL*	0.53	0.62	0.54	0.63	0.84	*1.00*	/	/
θ_RP165	0.21	0.48	−0.45	−5.24	−3.87	−7.71	−33.12	−54.70
θ_P165	0.46	0.69	0.50	0.63	0.82	0.88	0.74	0.82
θ_P90	0.47	0.70	0.55	0.74	0.72	0.55	/	/
θ_L*	−0.50	−0.62	−0.25	−9.06	−28.42	−25.57	/	/
θ_oL*	0.40	0.31	0.42	0.50	0.54	0.55	/	/

Field Plot 3	**M_{1p}_10**	**M_{2p}_20**	**M_{3p}_37**	**M_{4p}_50**	**M_{5p}_65**	**M_{6p}_90**	**M_{7p}_120**	**M_{8p}_165**
h_RP165	0.46	0.41	0.29	0.09	0.34	0.76	0.77	*1.00*
h_P165	0.63	0.68	0.76	0.72	0.79	0.86	0.80	*1.00*
h_P90	0.64	0.69	0.76	0.80	0.85	*1.00*	/	/
h_L*	0.12	0.64	0.49	0.64	0.73	*1.00*	/	/
h_oL*	0.29	0.63	0.50	0.66	0.73	*1.00*	/	/
θ_RP165	−1.85	−8.63	−6.92	−22.11	−9.83	−2.58	−23.09	−0.04
θ_P165	0.45	0.36	0.54	0.61	0.70	0.85	0.72	0.91
θ_P90	0.46	0.37	0.56	0.67	0.75	0.73	/	/
θ_L*	−0.15	−0.69	0.44	−6.11	−44.23	−71.89	/	/
θ_oL*	0.38	0.30	0.50	0.52	0.57	0.78	/	/

Note: RP165 for results obtained with the parameters optimized with RetC, P165 for results obtained with the parameters optimized with HYDRUS-1D on the 165 cm deep profile; P90 for results obtained by applying the parameters optimized for the 165 cm deep profile to the 90 cm deep profile; L* for results obtained by applying the mean optimized parameters from the six lysimeters; oL*, the same as L* but for saturated water content values (θ_s*) again optimized for each soil material.

Table S5. Efficiency coefficients calculated for bromide transport for each monitoring campaign (C_1 to C_4) conducted on Field Plots 2 and 3 and based on different optimization procedures using HYDRUS-1D.

	C_1 (13 June 2013)	**C_2 (27 November 2013)**	**C_3 (01 August 2014)**	**C_4 (21 January 2015)**
Field Plot 2				
P165_CDE	0.53	0.86	0.68	0.95
P90_CDE	−0.03	0.86	0.83	/
L*_CDE	−1.29	0.88	−0.39	/
oL*_CDE	−0.79	0.84	−1.02	/
L*_MIM	−0.98	0.27	−2.09	/
oL*_MIM	−0.56	−0.03	−2.26	/
Field Plot 3				
P165_CDE	0.88	0.77	0.91	0.94
P90_CDE	0.74	0.77	0.73	/
L*_CDE	0.39	0.63	0.18	/
oL*_CDE	0.56	0.86	−0.68	/
L*_MIM	0.36	0.70	−1.75	/
oL*_MIM	0.67	0.47	−2.01	/

Note: P165 for results obtained with the parameters optimized with HYDRUS-1D on the 165 cm deep profile; P90 for results obtained by applying the parameters optimized for the 165 cm deep profile to the 90 cm deep profile; L* for results obtained by applying the mean optimized parameters from the six lysimeters; oL*, the same as L* but for saturated water content values (θ_s*) again optimized for each soil material. CDE for results obtained with the convection-dispersion equation. MIM for results obtained with the mobile-immobile model. Due to a lack of bromide in the 90 cm deep profile, efficiency coefficients were not calculated for the fourth monitoring campaign.

Table S6. Efficiency coefficients calculated for water content data at each depth instrumented in Lys. 4 using HYDRUS-1D.

	M_{1c}_10	**M_{2c}_20**	**M_{3c}_40**	**M_{4c}_60**	**M_{5c}_80**
θ_L	0.54	0.41	0.22	0.18	0.09
θ_P*	−0.42	−1.65	−71.12	−495.07	−103.90
θ_oP*	0.25	0.26	−0.01	−0.66	0.34

Note: L for results obtained with the parameters optimized with HYDRUS-1D on lysimeter data; P* for results obtained by applying the mean optimized parameters from 165 cm deep profile of the three field plots; oP*, the same as P* but for saturated water content values (θ_s*) again optimized for each soil material.

Table S7. Efficiency coefficients calculated for daily drainage data on Lys. 2, 3, 4, 5 and 6 using HYDRUS-1D.

	Lys. 2	**Lys. 3**	**Lys. 4**	**Lys. 5**	**Lys. 6**
d_L	0.85	0.80	0.77	0.78	0.72
CV	−2.3	−1.1	0.6	−1.0	−0.9
d_P*	0.82	0.82	0.82	0.81	0.80
CV	−16.7	−15.4	−6.2	−11.1	−10.9
d_oP*	0.82	0.82	0.81	0.81	0.79
CV	−16.9	−15.6	−6.3	−11.2	−11

Note: L for results obtained with the parameters optimized with HYDRUS-1D on lysimeter data; P* for results obtained by applying the mean optimized parameters from 165 cm deep profile of the three field plots; oP*, the same as P* but for saturated water content values (θ_s*) again optimized for each soil material. Coefficients of variation (CV) were calculated from cumulative experimental and simulated drainage data and are given in %.

Table S8. Parameters optimized using HYDRUS-1D for each of the six soil materials of Lys. 2, 3, 4, 5 and 6.

Soil Material	θ_s	K_s	θ_s	K_s	θ_s	K_s	θ_s	K_s	θ_s	K_s
	Lys. 2		Lys. 3		Lys. 4		Lys. 5		Lys. 6	
M_{1c}	*0.289*	*10.0*	*0.289*	*10.0*	**0.324** (0.324) [0.322–0.325] {0.322–0.325}	**31.2** [27.6–34.7]	*0.291*	*20.5*	*0.293*	*20*
M_{2c}	*0.288*	*1000.0*	*0.288*	*1000*	**0.298** (0.334) [0.297–0.299] {0.332–0.336}	**2067.2** [1839.0–2295.4]	*0.298*	*1411.9*	*0.298*	*1500.0*
M_{3c}	*0.307*	*44.9*	*0.307*	*44.9*	**0.307** (0.320) [0.306–0.308] {0.318–0.321}	44.9 [38.1–51.6]	*0.307*	*44.9*	*0.366*	*27.5*
M_{4c}	*0.389*	*199.3*	*0.389*	*32.4*	**0.407** (0.428) [0.406–0.408] {0.426–0.429}	**199.3** [71.4–328.6]	*0.407*	*199.3*	*0.407*	*100*
M_{5c}	*0.399*	*25*	*0.396*	*24.9*	0.399 (0.400) [0.398–0.400] {0.399–0.402}	***10.0***	*0.396*	*25*	*0.396*	*17.5*

Note: Initial parameters are given in parentheses after the optimized value. Confidence intervals associated with parameters optimized using HYDRUS-1D are given in brackets. Parameters θ_r, θ_s, α, n and K_s optimized using HYDRUS-1D are highlighted: (i) in **bold** for parameters whose **set value is not included in the initial bounds**, (ii) in *italics* for parameters *that were set manually*. Saturated water content values re-optimized during the cross simulations (θ_s*) are given in parentheses after the optimized value of θ_s and confidence intervals associated with θ_s* are given in braces.

Table S9. Values of dispersivity, immobile water content and mass exchange coefficient parameters manually set using HYDRUS-1D for all soil materials of Lys. 2, 3, 4, 5 and 6.

	Lys. 2	**Lys. 3**	**Lys. 4**	**Lys. 5**	**Lys. 6**
λ (cm)	1.00	0.75	1.00	1.00	0.75
θ_{im} (cm^3 cm^{-3})	0.065	0.065	0.075	0.090	0.080
C_0* (g m^{-2})	50.7	53.9	50.0	51.8	49.1
α_{ph} (d^{-1})	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-6}

Note: Initial amounts of bromide manually re-optimized are noted C_0*.

Table S10. Efficiency coefficients calculated for bromide concentration and cumulated outflow as a function of time (and cumulative drainage in parentheses) from Lys. 2, 3, 4, 5 and 6 and based on different optimization procedures using HYDRUS-1D.

		Lys. 2	**Lys. 3**	**Lys. 4**	**Lys. 5**	**Lys. 6**
Concentration	L_CDE	0.51 (0.69)	0.47 (0.63)	0.48 (0.58)	0.27 (0.44)	0.33 (0.46)
	L_MIM	0.89 (0.93)	0.83 (0.93)	0.84 (0.85)	0.90 (0.96)	0.83 (0.93)
	P*_CDE	0.35 (0.74)	0.34 (0.71)	0.52 (0.66)	0.29 (0.67)	0.32 (0.65)
	P*_MIM	0.82 (0.55)	0.79 (0.53)	0.75 (0.64)	0.83 (0.82)	0.80 (0.69)
Cumulated Outflow	L_CDE	0.16 (0.10)	0.24 (0.05)	0.45 (−0.41)	0.01 (−0.42)	−0.27 (−0.08)
	L_MIM	0.54 (0.64)	0.63 (0.45)	0.78 (0.20)	0.67 (0.45)	0.59 (0.65)
	P*_CDE	0.15 (0.62)	0.20 (0.49)	0.46 (−0.05)	0.12 (−0.20)	0.06 (0.36)
	P*_MIM	0.55 (0.64)	0.59 (0.48)	0.71 (0.29)	0.58 (0.06)	0.64 (0.16)

Note: L_CDE for results obtained with the convection-dispersion equation and parameters optimized with HYDRUS-1D on lysimeter data; L_MIM for results obtained with the mobile-immobile model and parameters optimized with HYDRUS-1D on lysimeter data; P*_CDE for results obtained with the convection-dispersion equation and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots; P*_MIM for the results obtained with the mobile-immobile model and by applying the mean optimized parameters from the 165 cm deep profiles of the three field plots.

Table S11. Mean values of the parameters optimized using HYDRUS-1D on the lysimeter data used for cross simulations on field plot data.

Layer	Soil Material	θ_r (cm³ cm⁻³)	θ_s (cm³ cm⁻³)	α (cm⁻¹)	n (-)	K_s (cm d⁻¹)
LAca	M_{1c}	0.062	0.294	0.020	1.194	17.1
	M_{2c}	0.097	0.293	0.200	1.050	1134.8
ASca	M_{3c}	0.109	0.353	0.035	1.100	123.7
Sca	M_{4c}	0.065	0.403	0.012	1.140	150.4
	M_{5c}	0.058	0.398	0.009	1.150	61.2

Note: To take into account the characteristics of the soil materials defining the soil profiles of the field plots and lysimeters, the parameters obtained for M_{1c}, M_{2c}, M_{4c} and M_{5c} were respectively applied to M_{1p}, M_{2p}, M_{5p} and M_{6p}. Parameters obtained for M_{3c} were applied to M_{3p} and M_{4p}.

Table S12. Mean values of the parameters optimized on the three field plots using HYDRUS-1D for cross simulations on lysimeter data.

Layer	Soil Material	θ_r (cm^3 cm^{-3})	θ_s (cm^3 cm^{-3})	α (cm^{-1})	n (-)	K_s (cm d^{-1})	λ (cm)
LAca	M_{1p}	0.064	0.355	0.020	1.230	56.6	2.7
	M_{2p}	0.075	0.359	0.034	1.224	642.4	2.7
ASca	M_{3p}	0.087	0.356	0.041	1.125	207.9	4.3
	M_{4p}	0.072	0.332	0.030	1.215	99.3	4.3
Sca	M_{5p}	0.047	0.351	0.016	1.273	24.2	2.0
	M_{6p}	0.045	0.340	0.007	1.554	16.7	2.0

Note: To take into account the characteristics of the soil materials defining the soil profiles of the field plots and lysimeters, the parameters obtained for M_{1p}, M_{2p}, M_{3p} M_{5p} and M_{6p} were respectively applied to M_{1c}, M_{2c}, M_{3c} M_{4c} and M_{5c}.