Supporting information for [Estimating the degree of preferential flow to drainage in an agricultural clay till field for a 10-year period].

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1 Introduction

The supporting information of this paper includes all extra datasets that are necessary for a deep understanding of the presented problem. The datasets cover the topographical information, geological mapping and groundwater potential heads of the Silstrup field. In addition to the field information, the laboratory results of the soil water retention and conductivity test are presented. Additional figures describe the sensitivity output for each sub-objective and for each macropore setting (MSET) with the P3 and P4 lower boundary conditions. Furthermore, the tables and extra figures include the final calibrated result for each test scenario with their respective retention and conductivity calibrated parameter values.

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3 Field characteristics and field instrumentation

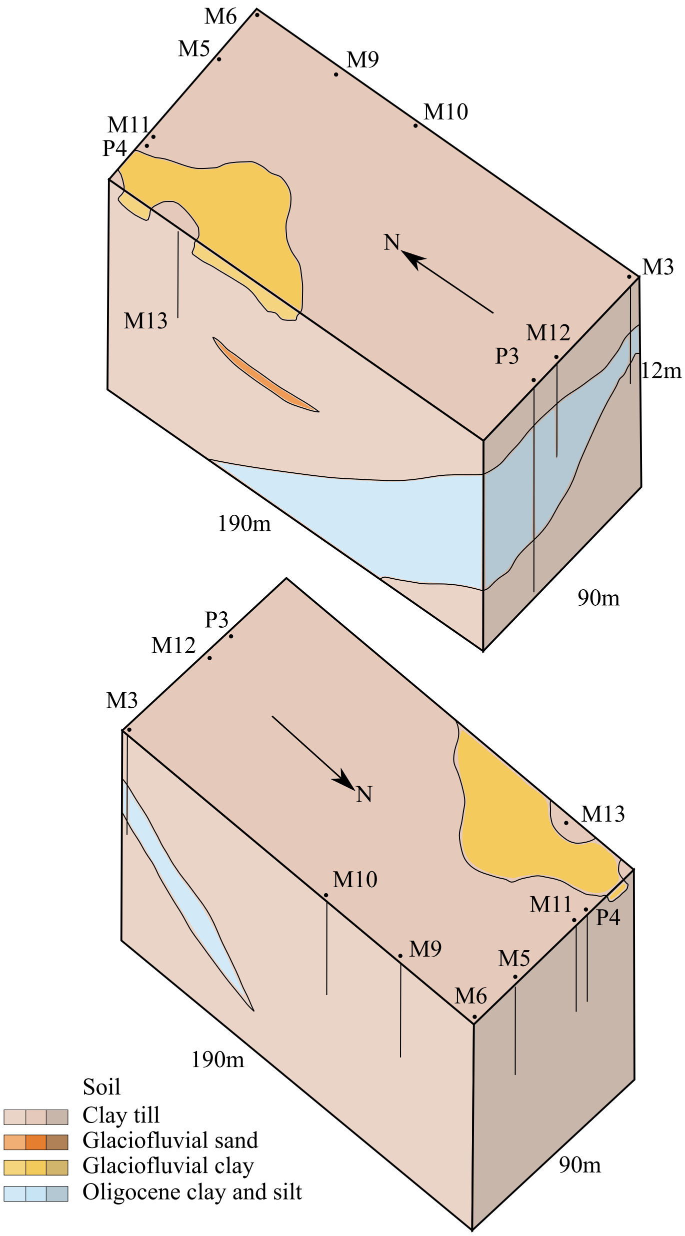

Figure S1. A geological model of the Silstrup field. M marks the location of groundwater wells and P the locations of the piezometers for monitoring groundwater level.

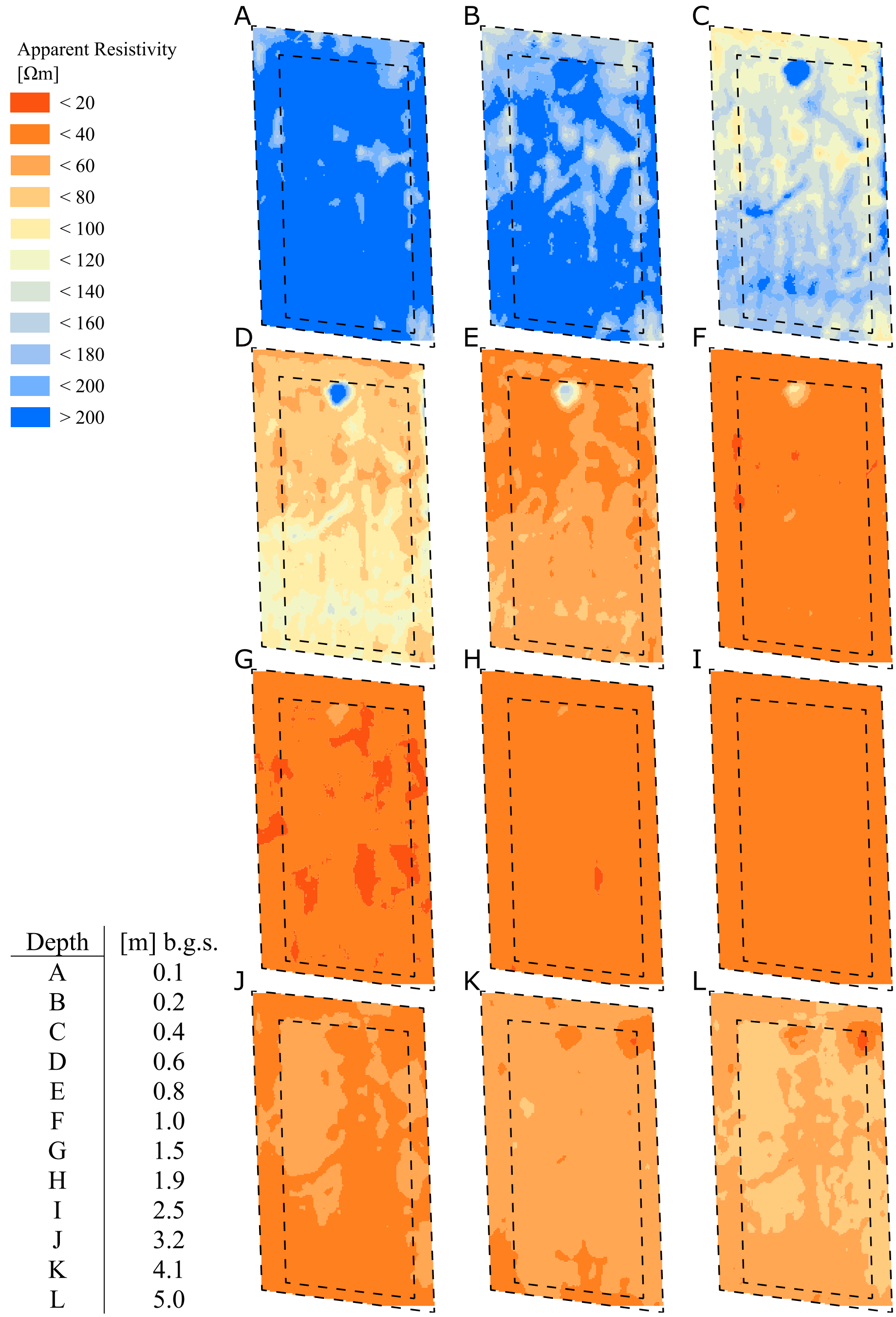

Figure S2. Topography and field instrumentation of the Silstrup field.

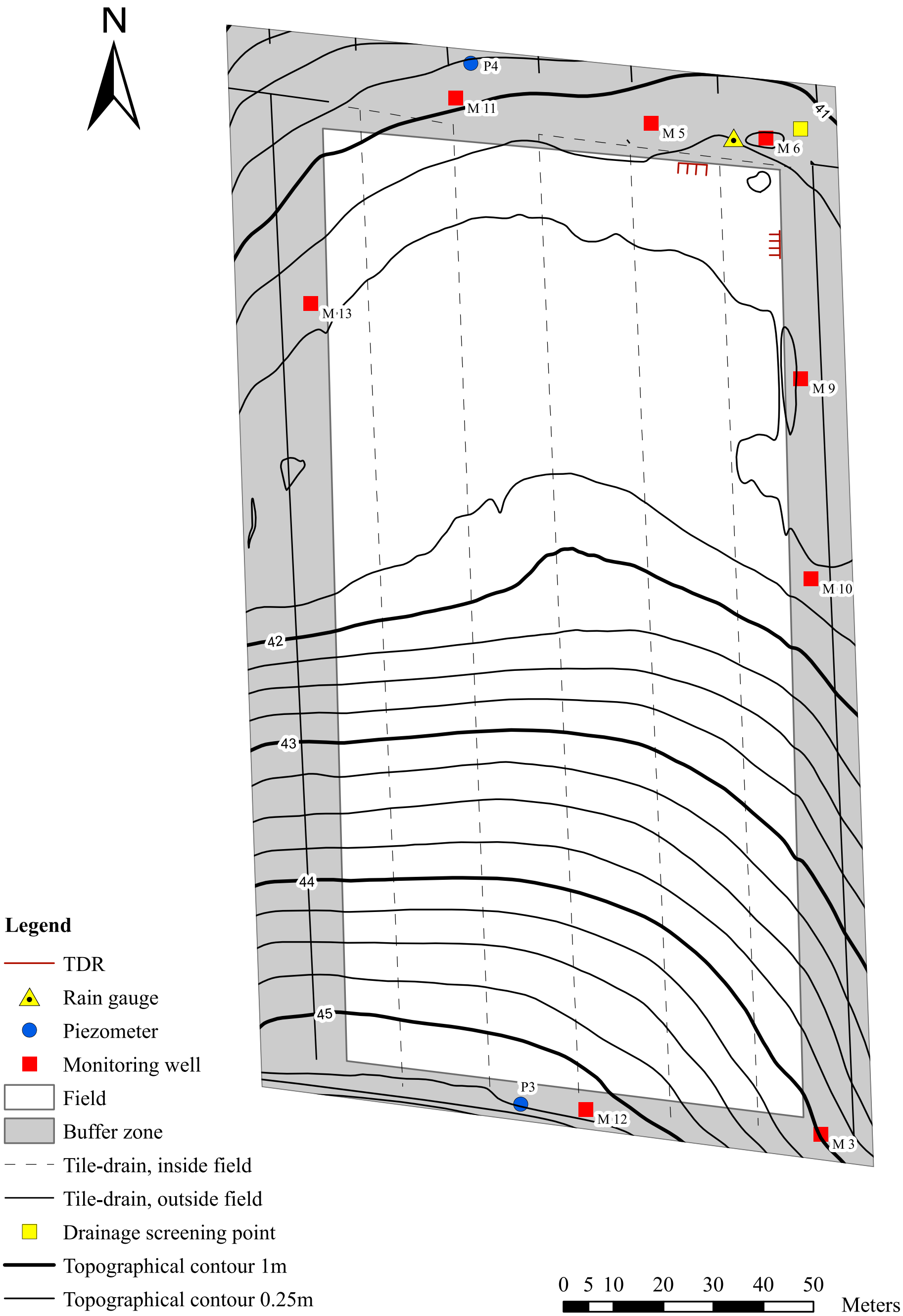

Figure S3. Potential head (m.a.s.l.) contour lines of the field measured in February 2000.

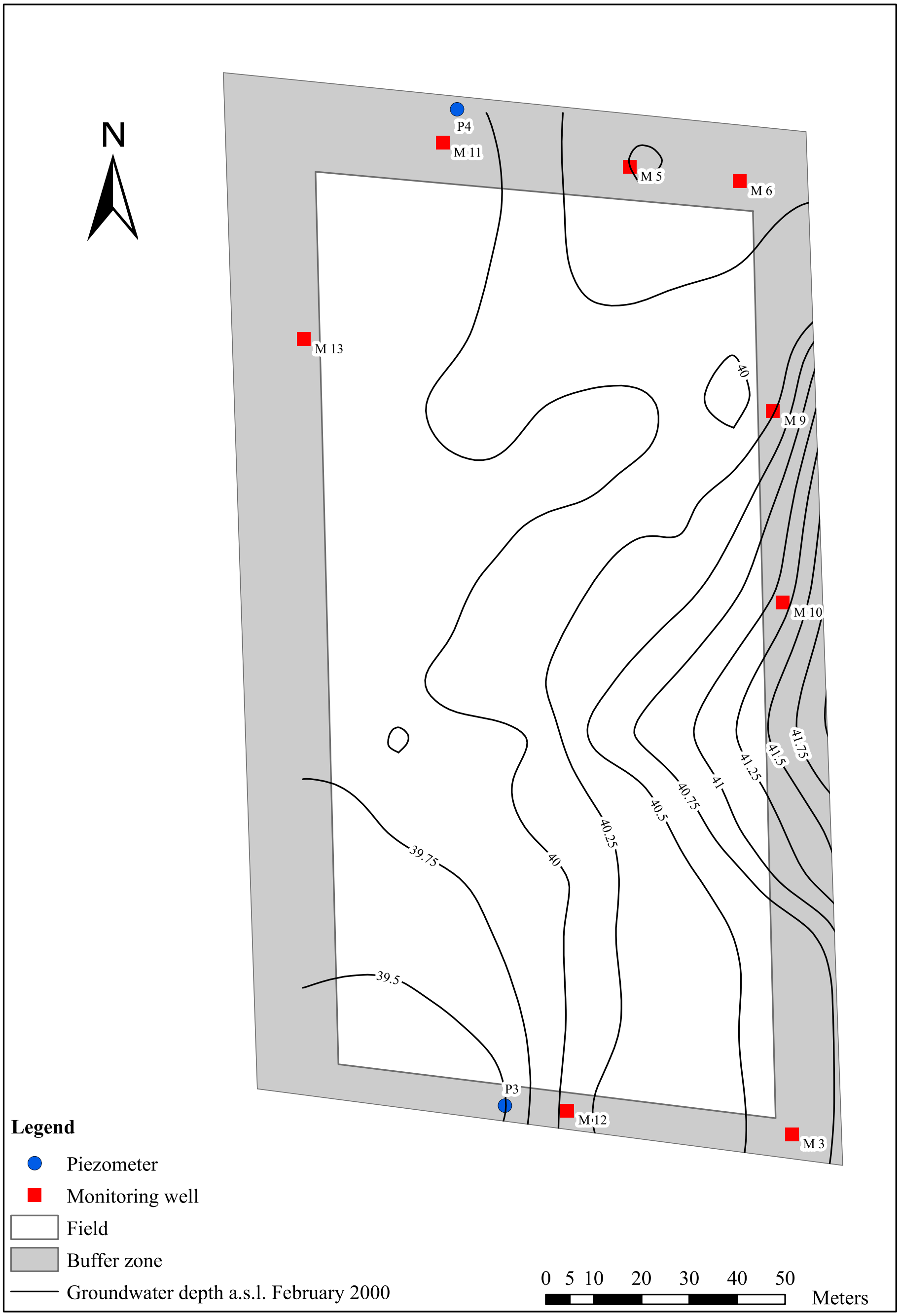

Figure S4. Apparent resistivity measurement of the field.

3.1 Field instrumentation description supplement (Lindhardt et al., 2001)

The automated system consists of various items of hardware and sensors and commercially available software tools in which dedicated software codes have been implemented. The central unit is a Campbell CR10X 2M datalogger (Campbell Sci, UK). User communication from an office PC to this datalogger is established via a modem using fixed telephone lines or GSM phone transmission. The data is collected automatically every night.

An automated monitoring system has been installed to measure precipitation, barometric pressure, soil temperature, soil water content and drainage flow. Further, the datalogger was programmed to control ISCO samplers (ISCO 5800 Refrigerated Sampler, Teledyne ISCO, USA) to take flow-proportional samples of the drainage water from which total nitrogen and nitrate were assessed using standard analysis methods in the lab.

3.2 Precipitation

Precipitation is measured on site with a tipping bucket rain gauge (Type 1518Wilh. Lambrecht, BmbH, Germany). The gauge is accurate to 0.1 mm and is well suited to measuring high precipitation intensity. Sampling is carried out every minute and hourly values are stored.

3.3 Soil water content

Soil water content is measured using a CR10X-controlled Time Domain Reflectometry (TDR)-system. The central unit in the TDR-system is the cable tester from Tektronix 1502C (Tektronix Inc., Beaverton, OR, USA). The soil water probes are developed at Research Centre Foulum and consist of a 40-m coaxial cable (Mikkelsen Electronic A/S, DK) connected through a solid plastic box to three 30-cm steel rods spaced about 2 cm apart. The accuracy of the soil water measurements is around ± 1 vol %. Soil water content is measured in two profiles at each site at the depths of 0.25, 0.6, 0.9, 1.1, 1.9 and 2.1 m, with three replicate probes at each depth. Soil water content is measured and stored every hour.

3.4 Soil water retention data from PLAP

The laboratory SWR measurements were done on 100-cm^3 soil samples, with nine replicates at each horizon and face. The mean of the SWR measurement of the corresponding Face and Horizon is presented below. The saturated and unsaturated hydraulic conductivity measurements were done on 6280-cm^3 large, undisturbed soil columns. The measurements and measurement algorithm were done by Iversen et al. (2004).

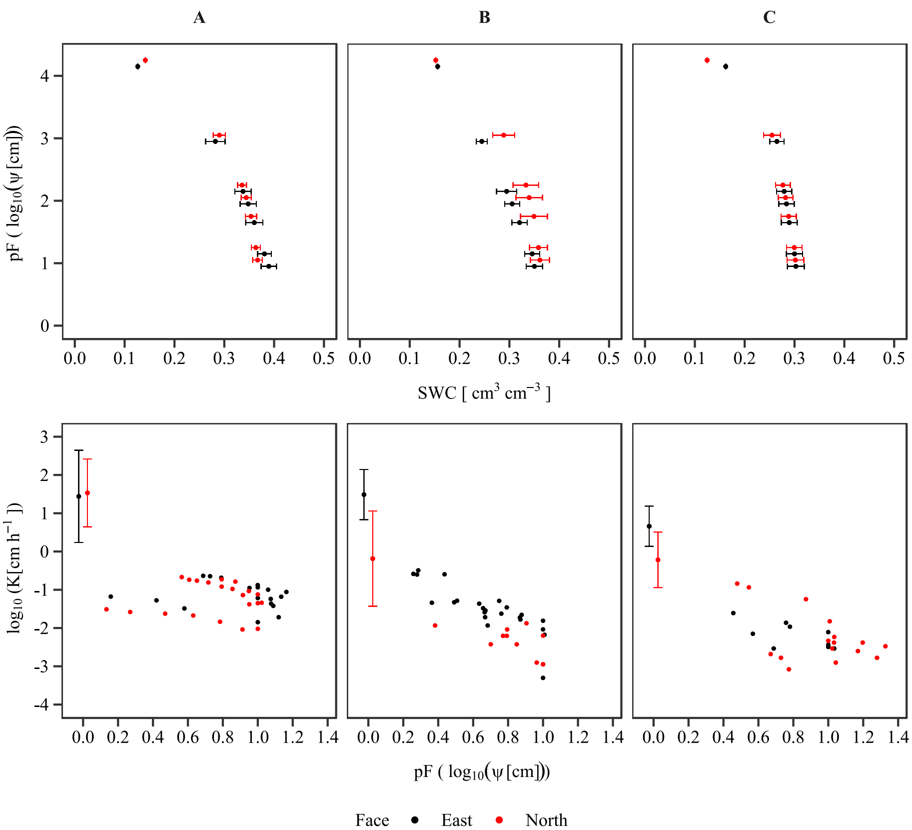

Figure S5. Soil water retention measured in the laboratory (mean of 7-9 soil cores ±SD, Table S2) at various soil water potentials (Table S1) on soil samples from the North and East pedological profiles (top figure) in the A-, B- and C-horizons. Unsaturated hydraulic conductivity (Kunsat) is presented as a function of Log_{10} of the soil water potential and the saturated hydraulic conductivity (K_s) (mean of 4-5 soil core ±SD)(bottom figure).

Table S1. Laboratory measured mean soil water retention of function of Log10 of soil water potential, bulk density and porosity. (P = Profile, H = Horizon, BD = Bulk Density)

P.	H.	D.	Water content at pF values $[cm^3\,cm-3]$							BD	Porosity
		[cm]	1	1.2	1.7	2	2.2	3	4.2	$[g\,cm-3]$	$[cm^3\,cm-3]$
East	**A**	15	0.39	0.38	0.36	0.35	0.34	0.28	0.13	1.42	0.46
	±SD		0.02	0.01	0.02	0.02	0.02	0.02	0	0.07	0.03
	B	40	0.35	0.35	0.32	0.31	0.29	0.24	0.16	1.62	0.39
	±SD		0.02	0.02	0.02	0.02	0.02	0.01	0	0.03	0.01
	C	150	0.3	0.3	0.29	0.28	0.28	0.26	0.16	1.77	0.33
	±SD		0.02	0.02	0.02	0.02	0.02	0.01	0	0.05	0.02
North	**A**	15	0.37	0.36	0.35	0.34	0.34	0.29	0.14	1.54	0.42
	±SD		0.01	0.01	0.01	0.01	0.01	0.01	0	0.04	0.02
	B	40	0.36	0.36	0.35	0.34	0.33	0.29	0.15	1.59	0.4
	±SD		0.02	0.02	0.03	0.03	0.03	0.02	0	0.04	0.02
	C	90	0.3	0.3	0.29	0.28	0.28	0.25	0.12	1.75	0.34
	±SD		0.02	0.02	0.02	0.01	0.01	0.02	0	0.06	0.02

4 Results of Morris sensitivity screening

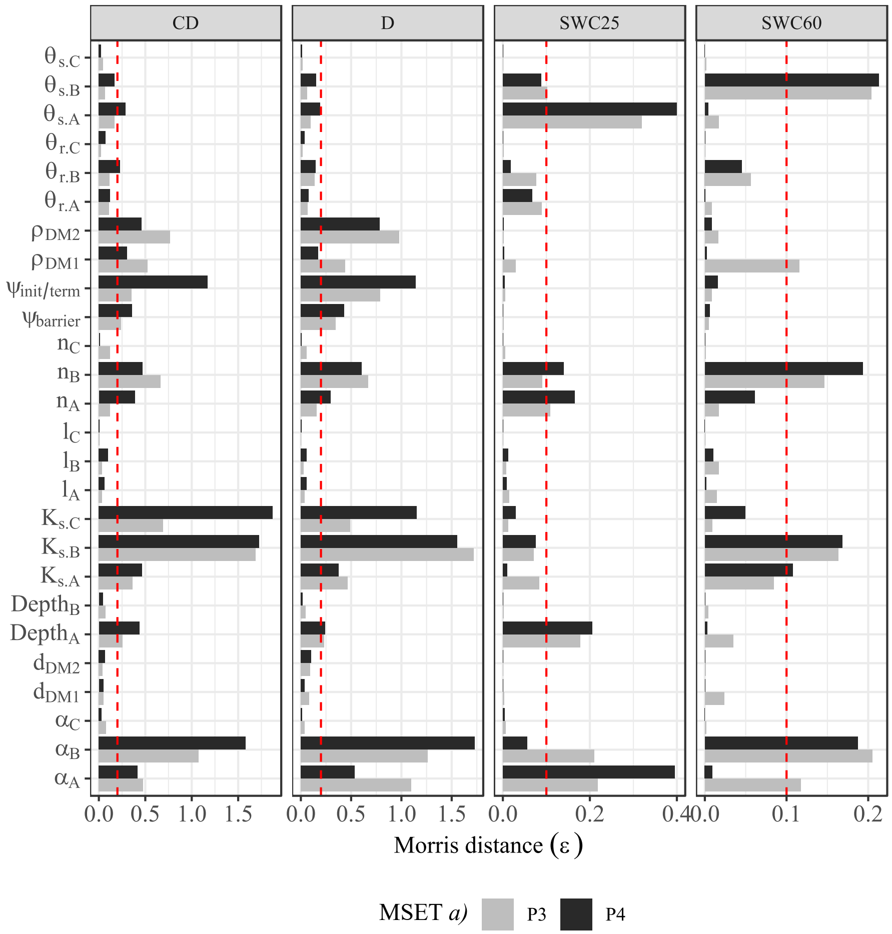

Figure S6. Morris sensitivity screening output with Morris distance of MSET *a)*, red lines represent the sensitivity threshold with respect to the sub-objectives.

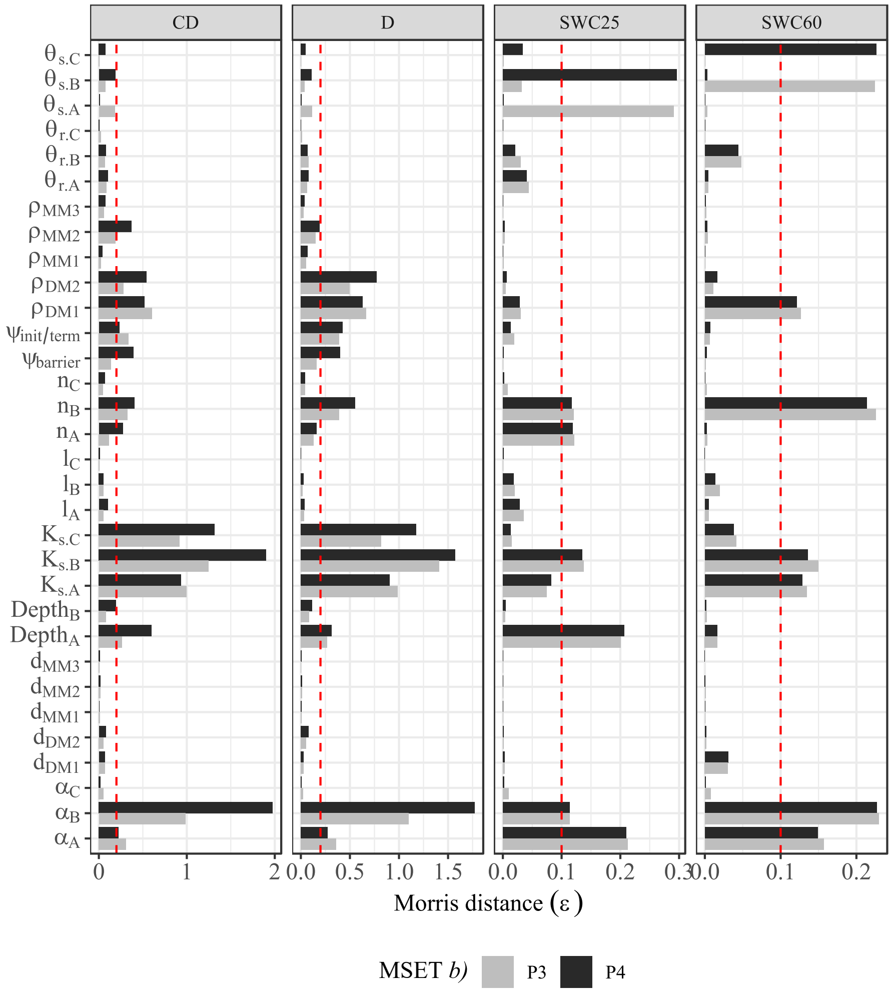

Figure S7. Morris sensitivity screening output with Morris distance of MSET *b)*, red lines represent the sensitivity threshold with respect to the sub-objectives.

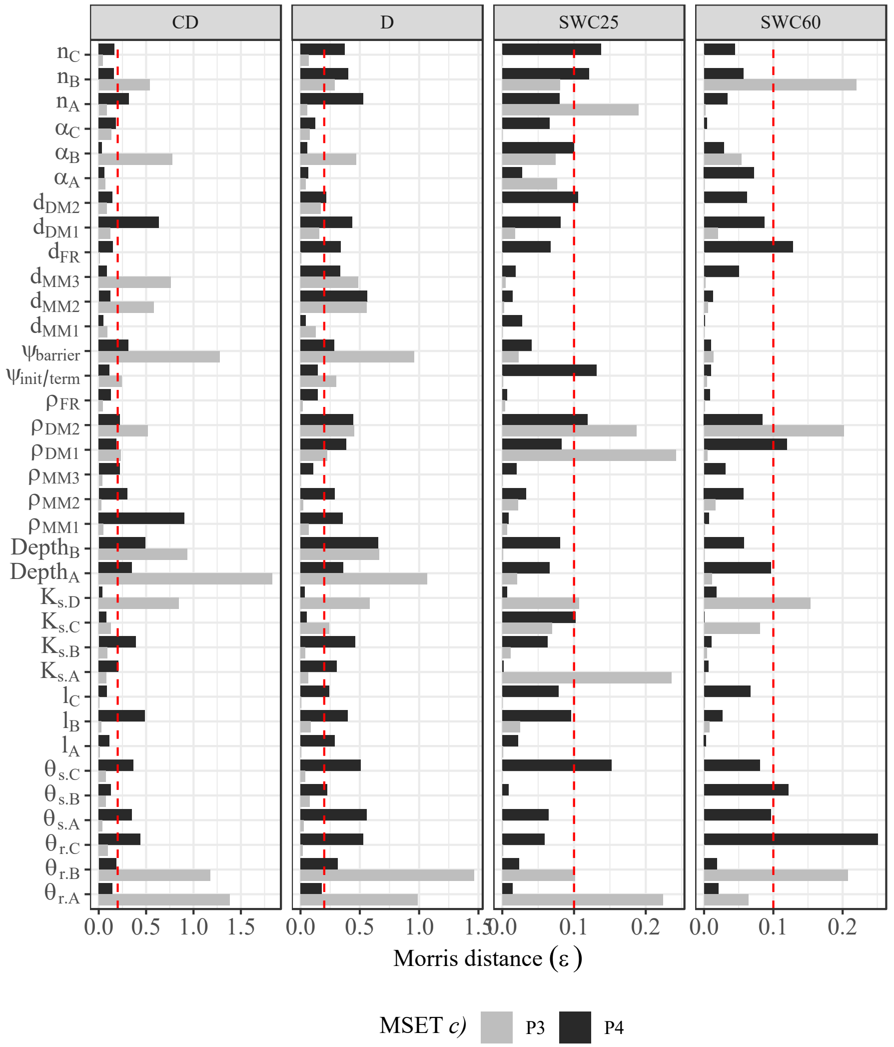

Figure S8. Morris sensitivity screening output with Morris distance of MSET *c)*, red lines represent the sensitivity threshold with respect to the sub-objectives.

5 Calibrated model results

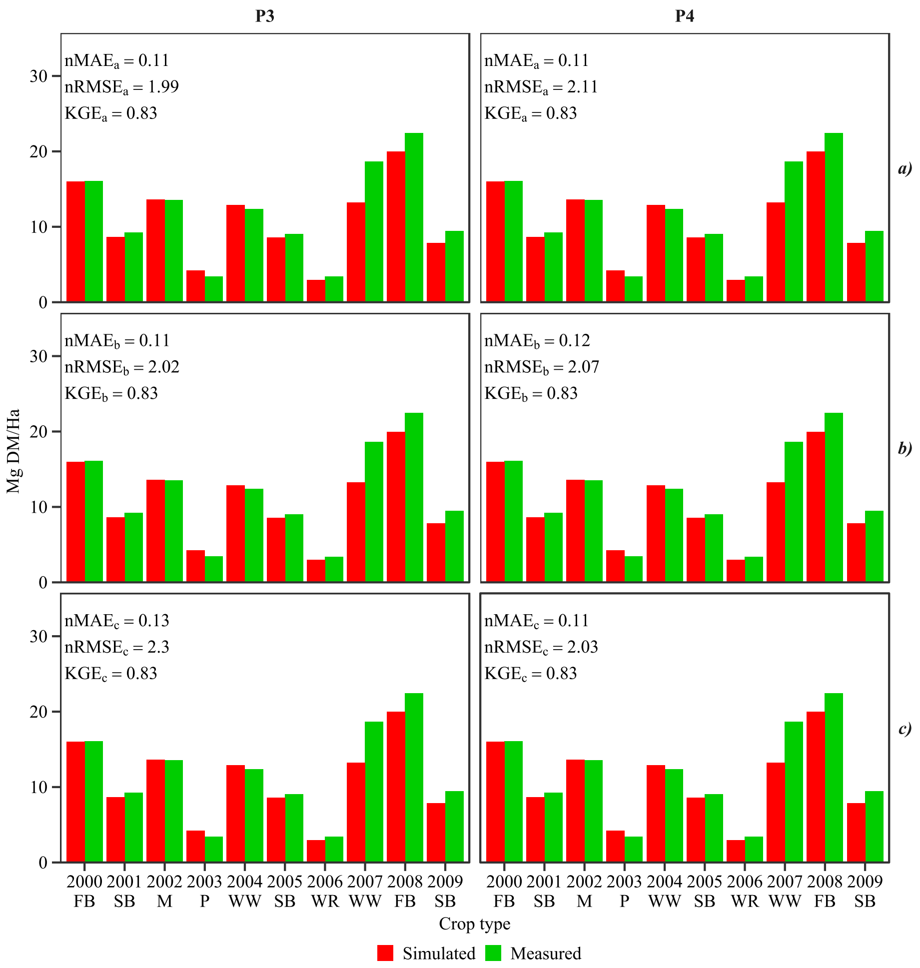

Figure S9. Simple calibrated harvested dry matter (DM) for MSET *a), b)* and *c)* with lower boundary P3 and P4 and nMAE, nRMSE[%], and KGE of the six models. FB: Fodder Beet, SB: Spring Barley, P: Pea, M: Maize, WW: Winter Wheat and WR: Winter Rape

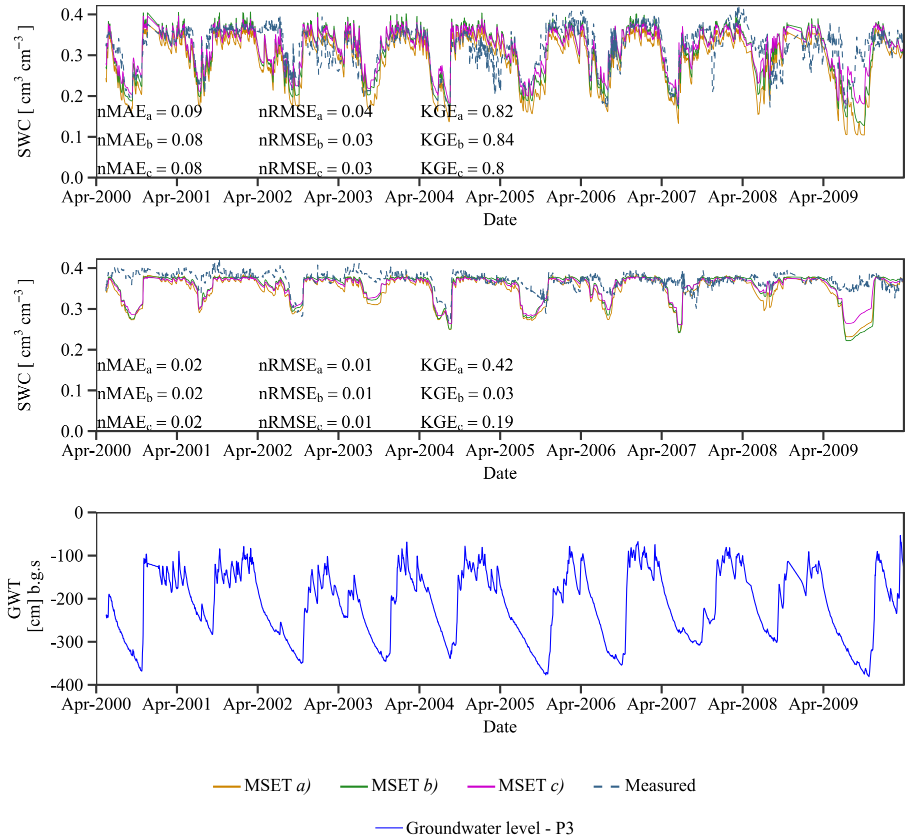

Figure S10. Calibrated soil water content at a depth of 25 cm (upper) and 60 cm (middle) for MSETs *a)*, *b)* and *c)* with lower boundary P3 (GWT, lower). nMAE, nRMSE[%], and KGE are given for the whole calibration period (2003-2008) for drainage.

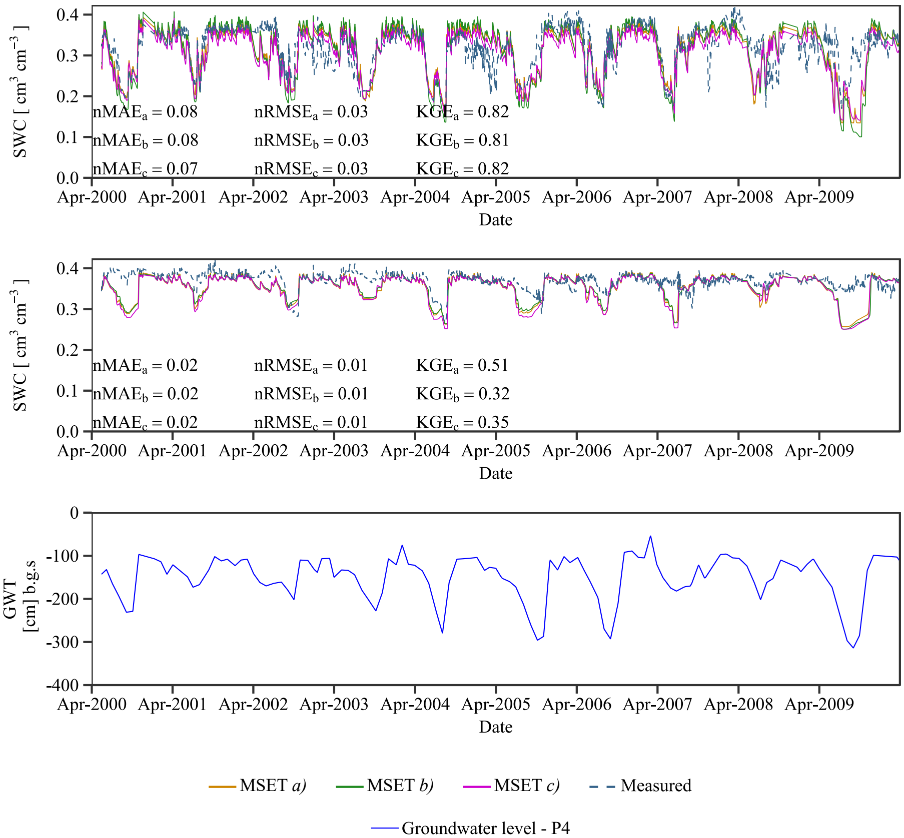

Figure S11. Calibrated soil water content at a depth of 25 cm (upper) and 60 cm (middle) for MSETs *a)*, *b)* and *c)* with lower boundary P4 (GWT, lower). nMAE, nRMSE[%], and KGE are given for the whole calibration period (2003-2008) for drainage.

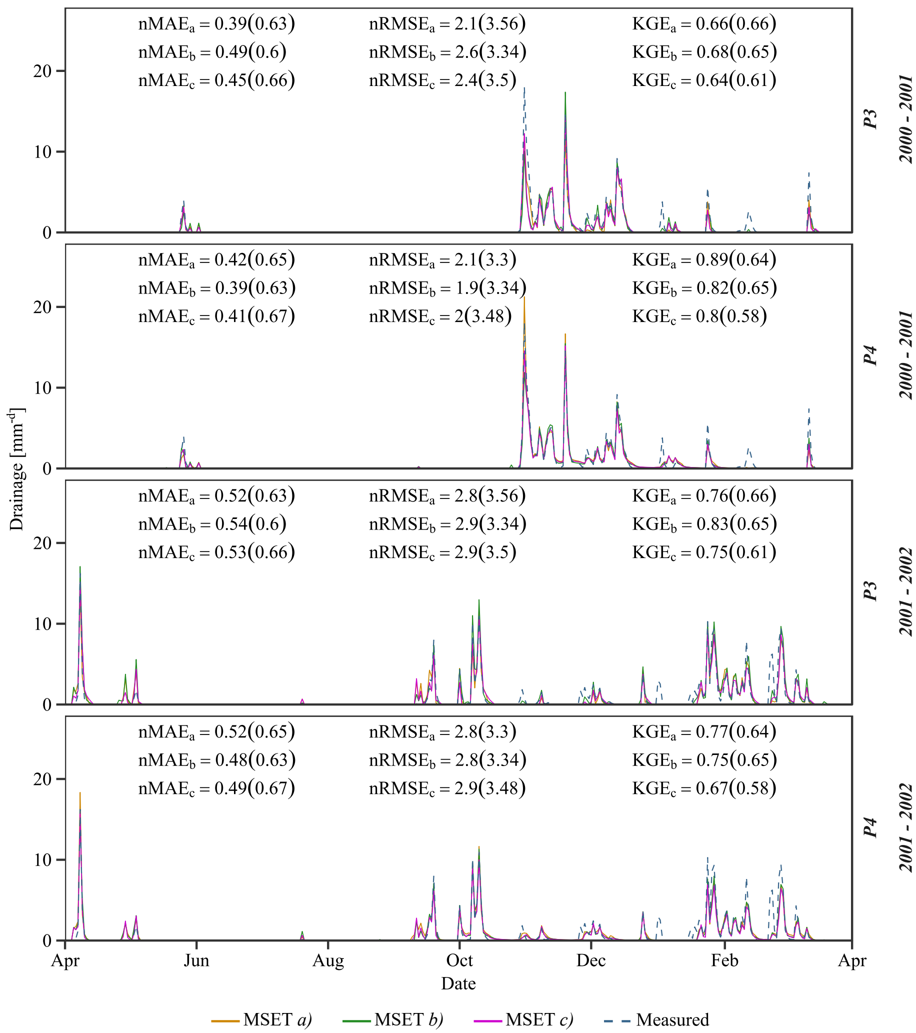

Figure S12. Performance of the six models (MSET *a)*, *b)* and *c)* applying the groundwater table from P3 and P4) when describing measured drainage for the evaluation period 2000-2001 and 2001-2002. nMAE, nRMSE[%] and KGE of the six models are given for the presented period with nMAE values in brackets for the whole calibration drainage period (2003-2008).

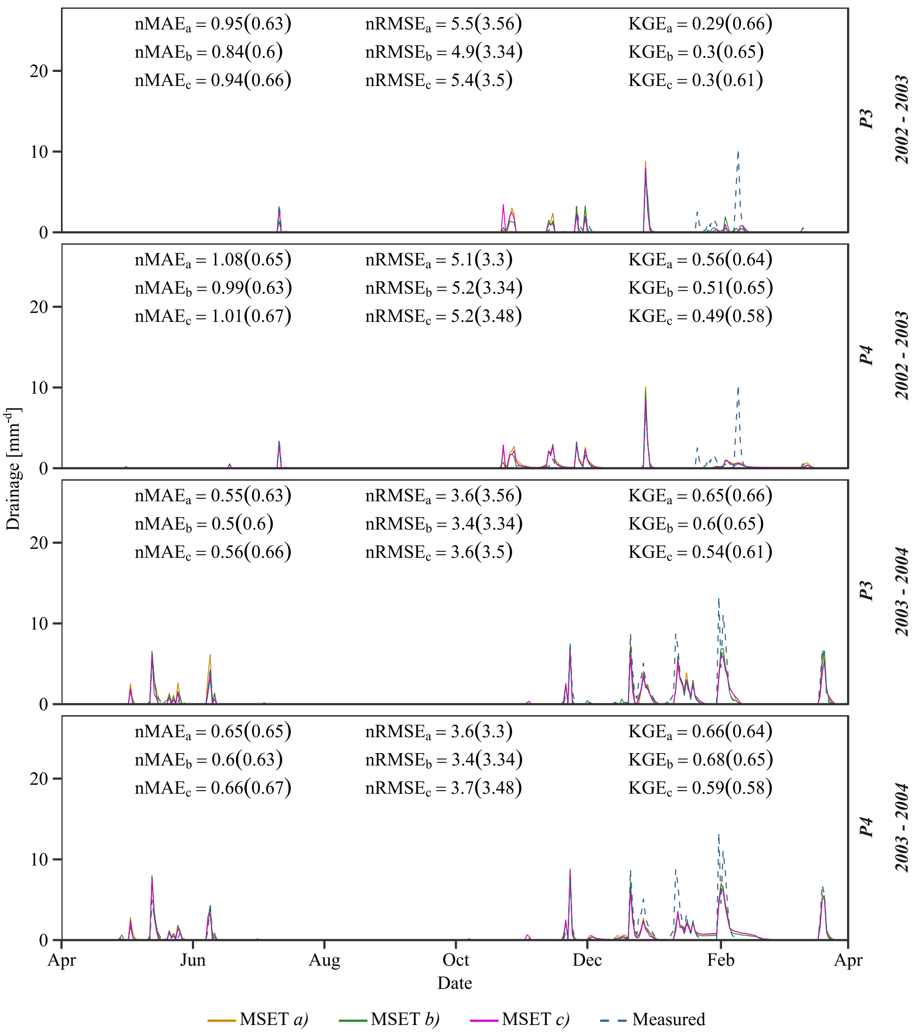

Figure S13. Performance of the six models (MSET *a)*, *b)* and *c)* applying the groundwater table from P3 and P4) when describing measured drainage for the evaluation period 2002-2003 and 2003-2004. nMAE, nRMSE[%] and KGE of the six models are given for the presented period with nMAE values in brackets for the whole calibration drainage period (2003-2008).

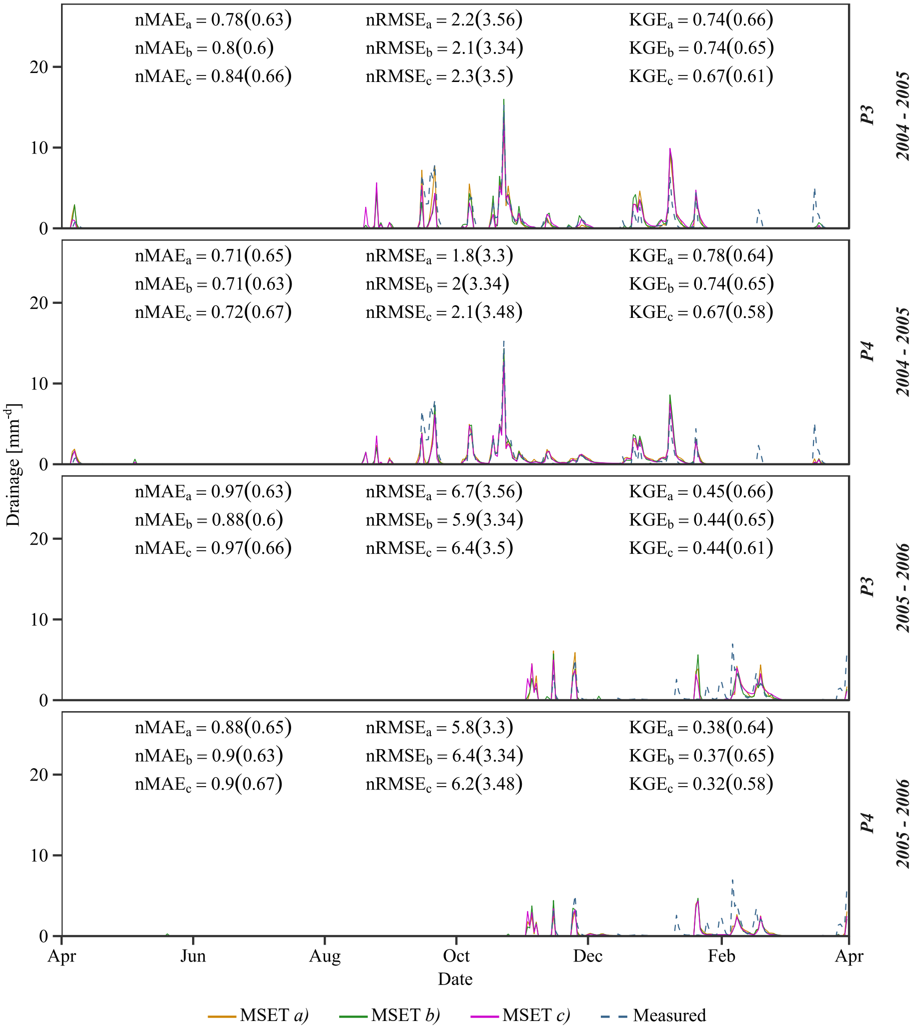

Figure S14. Performance of the six models (MSET *a)*, *b)* and *c)* applying the groundwater table from P3 and P4) when describing measured drainage for the evaluation period 2004-2005 and 2005-2006. nMAE, nRMSE[%] and KGE of the six models are given for the presented period with nMAE values in brackets for the whole calibration drainage period (2003-2008).

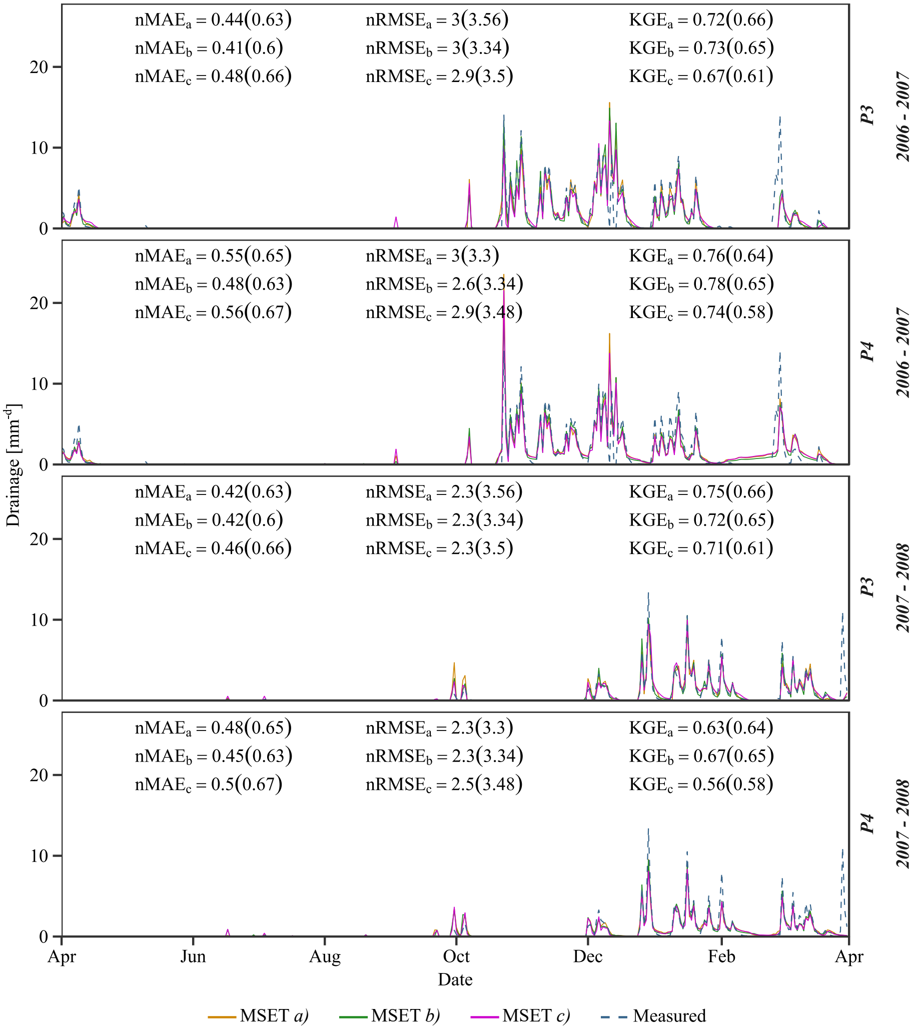

Figure S15. Performance of the six models (MSET *a)*, *b)* and *c)* applying the groundwater table from P3 and P4) when describing measured drainage for the evaluation period 2006-2007 and 2007-2008. nMAE, nRMSE[%] and KGE of the six models are given for the presented period with nMAE values in brackets for the whole calibration drainage period (2003-2008).

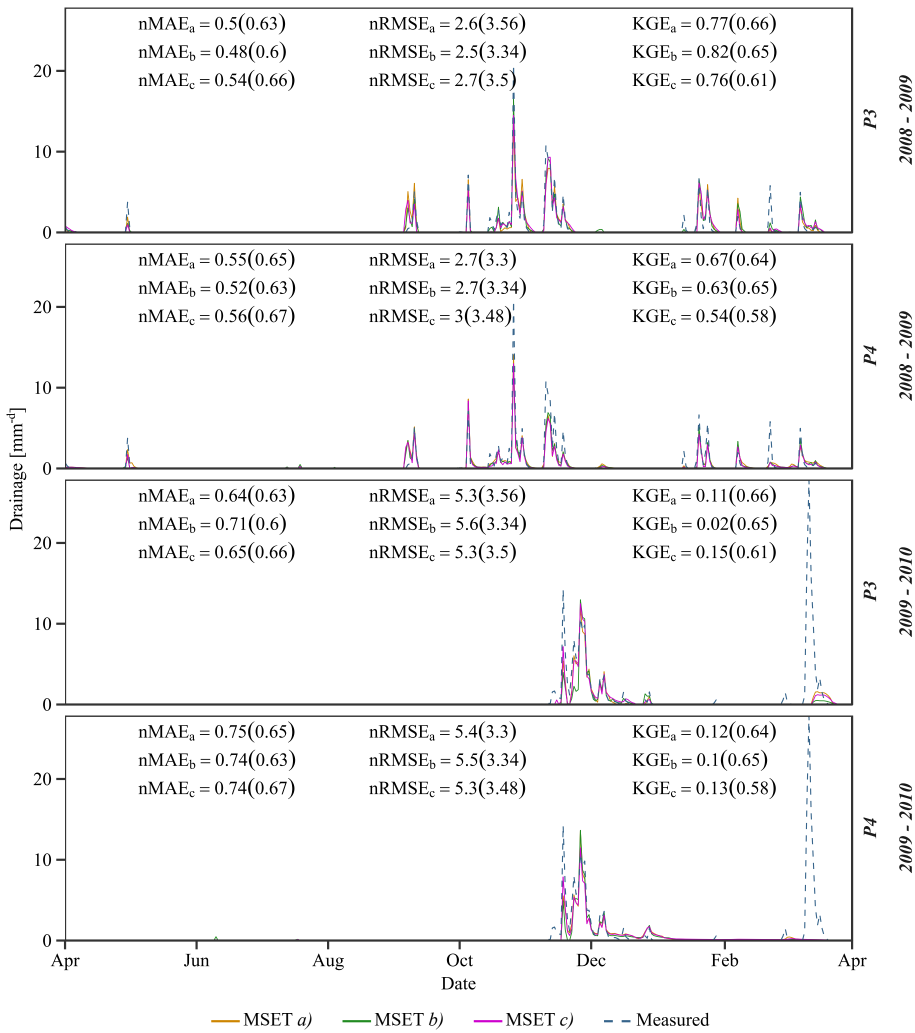

Figure S16. Performance of the six models (MSET *a)*, *b)* and *c)* applying the groundwater table from P3 and P4) when describing measured drainage for the evaluation period 2008-2009 and 2009-2010. nMAE, nRMSE[%] and KGE of the six models are given for the presented period with nMAE values in brackets for the whole calibration drainage period (2003-2008).

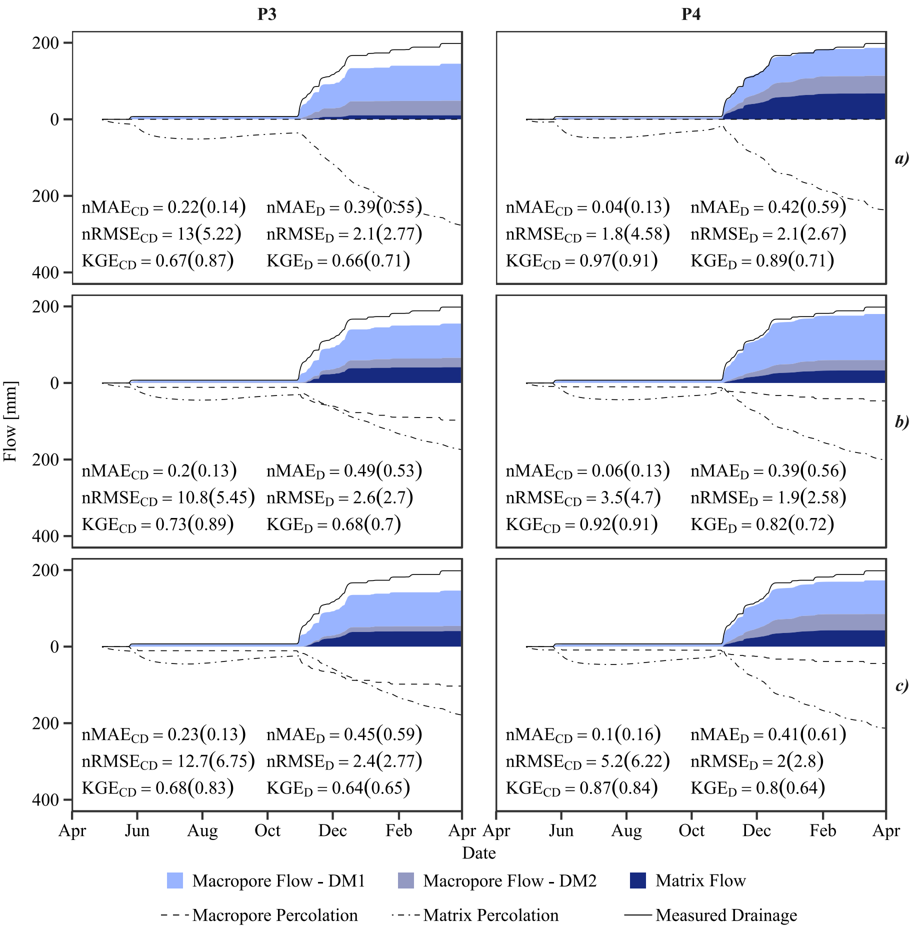

Figure S17. Simulated accumulated drainage input from matrix and macropore domains, accumulated matrix and macropore percolation, and measured drainage with the corresponding nMAE, nRMSE[%] and KGE for 2000-2001 drainage at 1.1 m drain level for all the six model setups with values in brackets for the whole calibration drainage period (2003-2008).

Table S2. Final calibrated parameters of MSETs *a)*, *b)* and *c)* with lower boundary conditions P3 and P4. Non-sensitive parameter for P3 and P4 marked in gray color.

Parameter	***a)***		***b)***		***c)***	
	P3	**P4**	**P3**	**P4**	**P3**	**P4**
$\theta_{r,A}$ [cm^3 cm^{-3}]	0.01	0.028	0.01	0.01	0.011	0.01
$\theta_{r,B}$ [cm^3 cm^{-3}]	0.013	0.076	0.013	0.013	0.097	0.072
$\theta_{r,C}$ [cm^3 cm^{-3}]	0.01	0.01	0.01	0.01	0.01	0.01
$\theta_{s,A}$ [cm^3 cm^{-3}]	0.3974	0.3998	0.4063	0.4143	0.433	0.4056
$\theta_{s,B}$ [cm^3 cm^{-3}]	0.3847	0.3895	0.3783	0.3874	0.3779	0.3851
$\theta_{s,C}$ [cm^3 cm^{-3}]	0.2938	0.2938	0.2938	0.2938	0.2938	0.2938
l_A [-]	0.5	0.5	0.5	0.5	-0.02	0.5
l_B [-]	0.5	0.5	0.5	0.5	0.5	0.5
l_C [-]	0.5	0.5	0.5	0.5	0.5	0.5
$K_{s,A}$ [cm h^{-1}]	21.21	17.1	10.71	1.49	32.45	19.56
$K_{s,B}$ [cm h^{-1}]	0.68	1.46	0.03	0.79	0.35	0.59
$K_{s,C}$ [cm h^{-1}]	0.56	0.19	0.28	0.21	0.18	0.27
α_A [-]	0.0308	0.023	0.051	0.0238	0.0833	0.0575
α_B [-]	0.0159	0.029	0.0045	0.0212	0.0112	0.0222
α_C [-]	0.001	0.001	0.001	0.001	0.001	0.0018
n_A [-]	1.2309	1.2143	1.186	1.2771	1.294	1.1645
n_B [-]	1.1128	1.1047	1.2005	1.1012	1.107	1.1141
n_C [-]	1.2154	1.2154	1.2154	1.2154	1.2154	1.2154
$Depth_A$ [cm]	-37.48	-39.69	-39.29	-38.93	-25.41	-39.91
$Depth_B$ [cm]	-140	-140	-140	-140	-140	-140
$\psi_{init/term}$ [cm]	-14.97	-11.89	-2.93	-14.74	-13.1	-9.89
$\psi_{barrier}$ [cm]	11.6	14.78	5	14.63	13.89	14.96
ρ_{DM1} [m^{-2}]	2.6	1.6	5.49	11.33	5.51	7.59
ρ_{DM2} [m^{-2}]	3.86	2.3	12.64	1.71	1.65	3.61
d_{DM1} [mm]	3	3	3	3	3	3
d_{DM2} [mm]	3	3	3	3	3	3
ρ_{MM1} [m^{-2}]	-	-	100	100	100	100
ρ_{MM2} [m^{-2}]	-	-	11.5	16.8	9.92	11.5
ρ_{MM3} [m^{-2}]	-	-	11.5	11.5	11.5	11.5
d_{MM1} [mm]	-	-	2	2	2	2
d_{MM2} [mm]	-	-	3	3	3	3
d_{MM3} [mm]	-	-	3	3	3	3
$K_{s,D}$ [cm h^{-1}]	-	-	-	-	30.08	4.99
ρ_{FR} [m^{-2}]	-	-	-	-	16	1.57
d_{FR} [mm]	-	-	-	-	0.1	0.37

References

Iversen, B. V. ., Koppelgaard, M. ., and Jacobsen, O. H.: An automated system for measuring air permeability and hydraulic conductivity in the laboratory on large soil cores, Report, Department of Agroecology, Aarhus University, 2004.

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