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Application of a novel cascade-routing and reinfiltration concept with a Voronoi unstructured grid in MODFLOW 6, for an assessment of surface-water/groundwater interactions in a hard-rock catchment (Sardon, Spain)

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Table S1 List of abbreviations and symbols

$\alpha_{i,j}$	Fraction of flow from the cell i to the neighbouring j cell
a_i	Land-cover class coverage fraction over the total catchment area for the calculations of E_{sf}
$\beta_{i,j}$	Flow partitioning factor used in model calibration
b_i	Land-cover class coverage fraction over the total catchment area for the calculations of PET
c	Fractional canopy cover
ΔS	Total catchment storage
ΔS_{g}	Groundwater zone storage
ΔS_{u}	Unsaturated zone storage
d_{ext}	Extinction depth
d_{surf}	Surface depth at which groundwater exfiltration can start
elv	Land surface elevation
E_{g}	Groundwater evaporation
E_{s}	Surface evaporation
E_{I}	Canopy interception
ET	Evapotranspiration
ET_{g}	Groundwater evapotranspiration
ET_{o}	Reference evapotranspiration
$\mathrm{ET}_{\mathrm{oc}}$	Reference evapotranspiration per unit area of canopy cover
$\mathrm{ET}_{\mathrm{ss}}$	Subsurface evapotranspiration
ET_{u}	Unsaturated zone evapotranspiration
$\mathrm{Exf}_{\mathrm{gw}}$	Groundwater exfiltration
$\mathrm{Exf}_{\mathrm{gw}}^{\mathrm{e}}$	Evaporated groundwater exfiltration
$\mathrm{Exf}_{\mathrm{gw}}^{\mathrm{i}}$	Reinfiltrated groundwater exfiltration
$\mathrm{Exf}_{\mathrm{gw}}^{\mathrm{r}}$	Groundwater exfiltration transferred down-gradient as runoff
$\mathrm{Exf}_{\mathrm{gw}}^{\mathrm{s}}$	Groundwater exfiltration routed to streams
I	Net infiltration
I_{a}	Active infiltration

K_{b}	Hydraulic conductivity of stream reach's bed
K_{c}	Crop coefficient
K_{cb}	Transpiration crop coefficient
K_{e}	Soil evaporation crop coefficient
K_{h}	Horizontal hydraulic conductivity
K_{sat}	Saturated vertical hydraulic conductivity
K_{v}	Vertical hydraulic conductivity
LAI	Leaf area index
$l_{i,j}$	Distance between the centres of the connected i and j cells
P	Precipitation
P_{e}	Effective precipitation
PET	Potential evapotranspiration
q	Total stream outflow at the catchment outlet
q_{B}	Baseflow
q_{g}	Lateral groundwater outflow
q_{gs}	Groundwater leakage to streams
Q.i.	*Quercus ilex*
Q.p.	*Quercus pyrenaica*
q_{sg}	Stream leakage to groundwater
$\overline{R}$	Mean rainfall intensity
$\mathrm{RE}^{\mathrm{i}} = (\mathrm{RI}^{\mathrm{i}} + \mathrm{Exf}_{\mathrm{gw}}^{\mathrm{i}})$	Total reinfiltrated water originated from the sum of RI^{i} and $\mathrm{Exf}_{\mathrm{gw}}^{\mathrm{i}}$
$\mathrm{RE}_{\mathrm{net}}^{\mathrm{i}} = \mathrm{RE}^{\mathrm{i}} - \mathrm{RI}^{\mathrm{r}}$	Net total reinfiltrated water
$\mathrm{RE}^{\mathrm{s}} = (\mathrm{RI}^{\mathrm{s}} + \mathrm{Exf}_{\mathrm{gw}}^{\mathrm{s}})$	Direct runoff originated from the sum of RI^{s} and $\mathrm{Exf}_{\mathrm{gw}}^{\mathrm{s}}$
R_{g}	Gross groundwater recharge
RI	Rejected infiltration
RI^{e}	Rejected infiltration evaporated
RI^{i}	Rejected infiltration reinfiltrated
RI^{r}	Rejected infiltration transferred down-gradient as runoff
$\mathrm{RI}_{\mathrm{net}}^{\mathrm{r}} = \mathrm{RI}^{\mathrm{r}} - \mathrm{RE}^{\mathrm{i}}$	Net rejected infiltration transferred down-gradient

RI^{s}	Rejected infiltration routed to streams
R_{n}	Net groundwater recharge
S	Canopy storage capacity
SAVI	Soil adjusted vegetation index
S_{c}	Canopy storage capacity per unit area of canopy cover
$S_{i,j}$	Slope gradient between cell i and j
S_{s}	Specific storage
S_{y}	Specific yield
θ_{i}	Initial water content
θ_{ext}	Extinction water content
θ_{resid}	Residual water content
θ_{sat}	Saturated water content

Table S2 Average monthly K_{e} and K_{cb} of the hydrological year 2010 for the land cover classes

Land cover class	Grass/bare soil		Outcrops		*Q.i.* on soil		*Q.i.* on outcrops		*Q.p.* on soil		*Q.p.* on outcrops	
b_i [-]	0.695		0.212		0.036		0.009		0.035		0.013	
Month	K_{e_1}	K_{cb_1}	K_{e_2}	K_{cb_2}	K_{e_3}	K_{cb_3}	K_{e_4}	K_{cb_4}	K_{e_5}	K_{cb_5}	K_{e_6}	K_{cb_6}
Oct-09	0.14	0.22	0.07	0.00	0.00	0.70	0.00	0.73	0.00	0.63	0.00	0.56
Nov-09	0.43	0.28	0.22	0.00	0.00	0.82	0.00	0.78	0.00	0.75	0.00	0.67
Dec-09	0.53	0.29	0.26	0.00	0.00	0.95	0.00	0.84	0.00	0.88	0.00	0.79
Jan-10	0.40	0.49	0.20	0.00	0.00	1.06	0.00	1.01	0.00	1.04	0.00	0.88
Feb-10	0.50	0.43	0.25	0.00	0.00	1.15	0.00	1.11	0.00	1.04	0.00	0.97
Mar-10	0.53	0.41	0.27	0.00	0.00	1.19	0.00	1.13	0.00	1.11	0.00	1.03
Apr-10	0.60	0.38	0.30	0.00	0.00	1.29	0.00	1.25	0.00	1.22	0.00	1.19
May-10	0.27	0.63	0.13	0.00	0.00	1.25	0.00	1.19	0.00	1.17	0.00	1.16
Jun-10	0.30	0.41	0.15	0.00	0.00	1.15	0.00	1.13	0.00	1.14	0.00	1.13
Jul-10	0.07	0.33	0.04	0.00	0.00	0.85	0.00	0.97	0.00	1.11	0.00	1.00
Aug-10	0.11	0.19	0.06	0.00	0.00	0.55	0.00	0.78	0.00	1.00	0.00	0.85
Sep-10	0.32	0.20	0.16	0.00	0.00	0.54	0.00	0.71	0.00	0.93	0.00	0.82

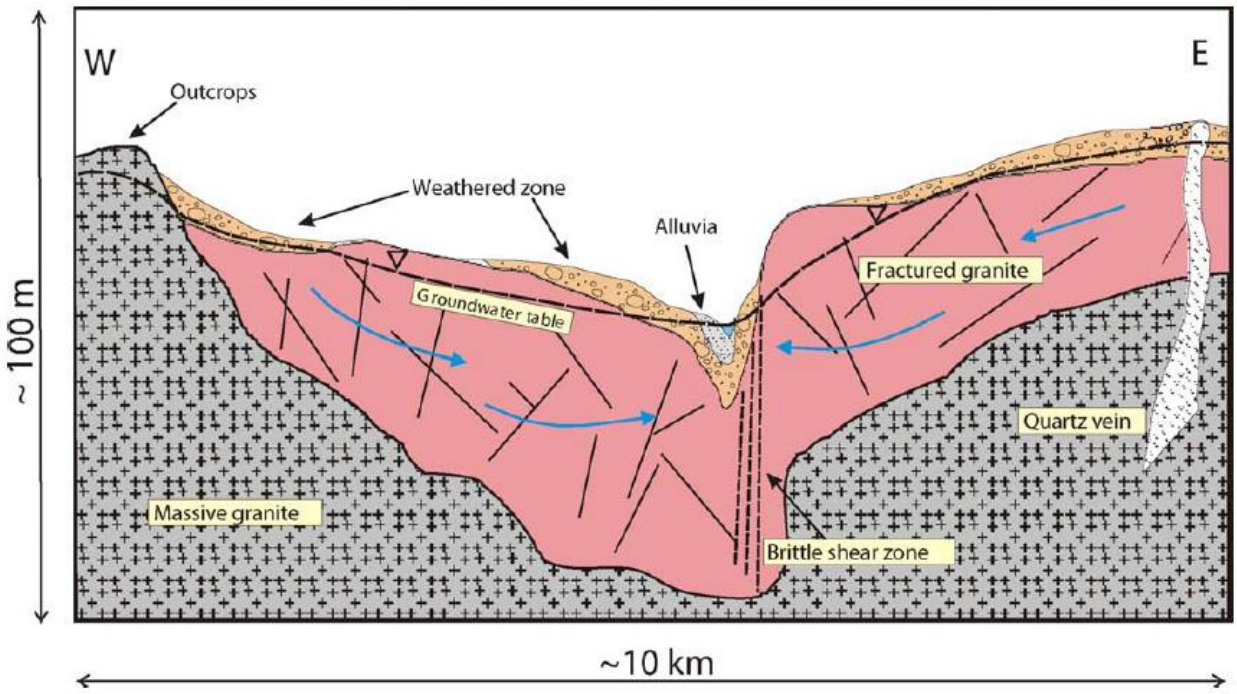

Fig. S1 Schematic cross-section after Lubczynski & Gurwin (2005)

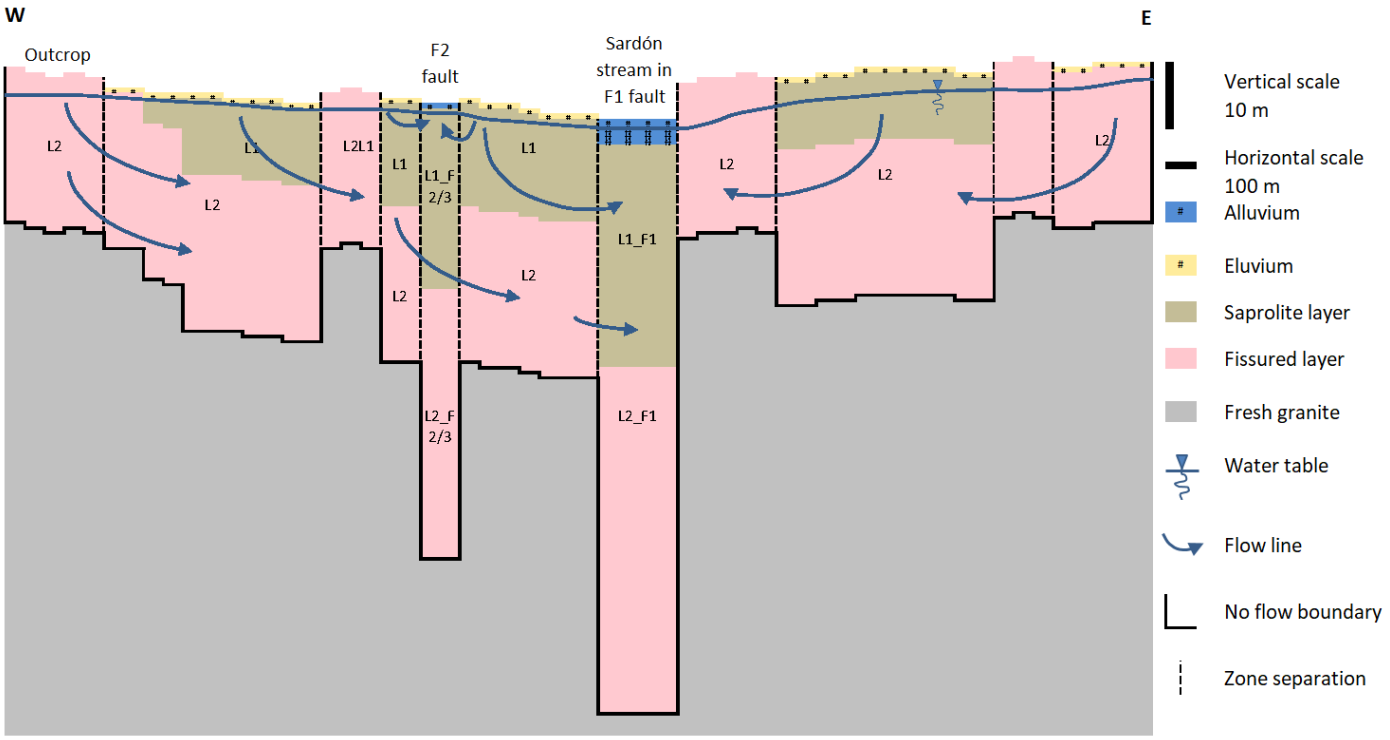

Fig. S2 Schematic cross-section after Francés et al. (2014)

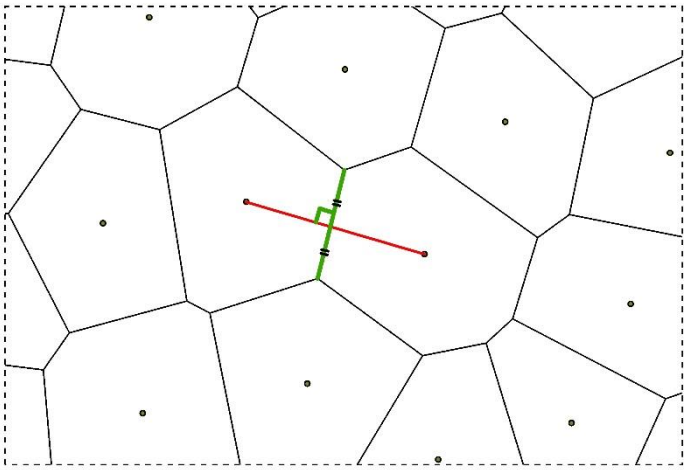

Fig. S3 CVFD requirements. The red line connecting the centers of the two cells should (1) intersect the shared edge at the right angle (*highlighted by the green line and the green angle symbols respectively*), and (2) bisect the shared edge (*highlighted by the equality signs*)

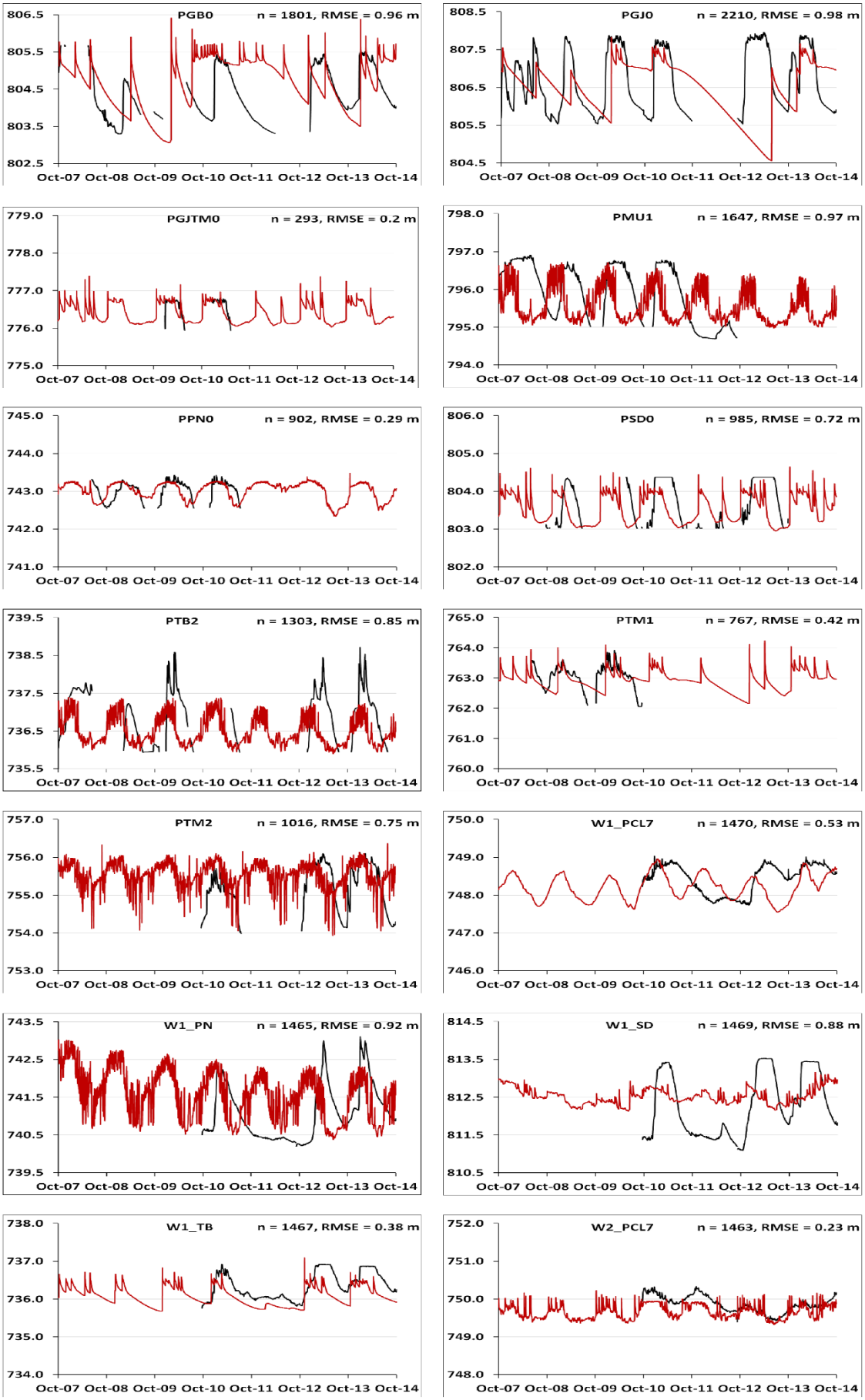

Fig. S4 Groundwater hydrographs: the simulated heads (*red lines*) versus the observed heads (*black lines*) at the 14 observation points within the study period (1 October 2007 – 30 September 2014); *n* is the number of daily records while RMSE is the root mean square error between simulated and observed heads; the locations of the head observation points are presented in Fig. 1 of the main article

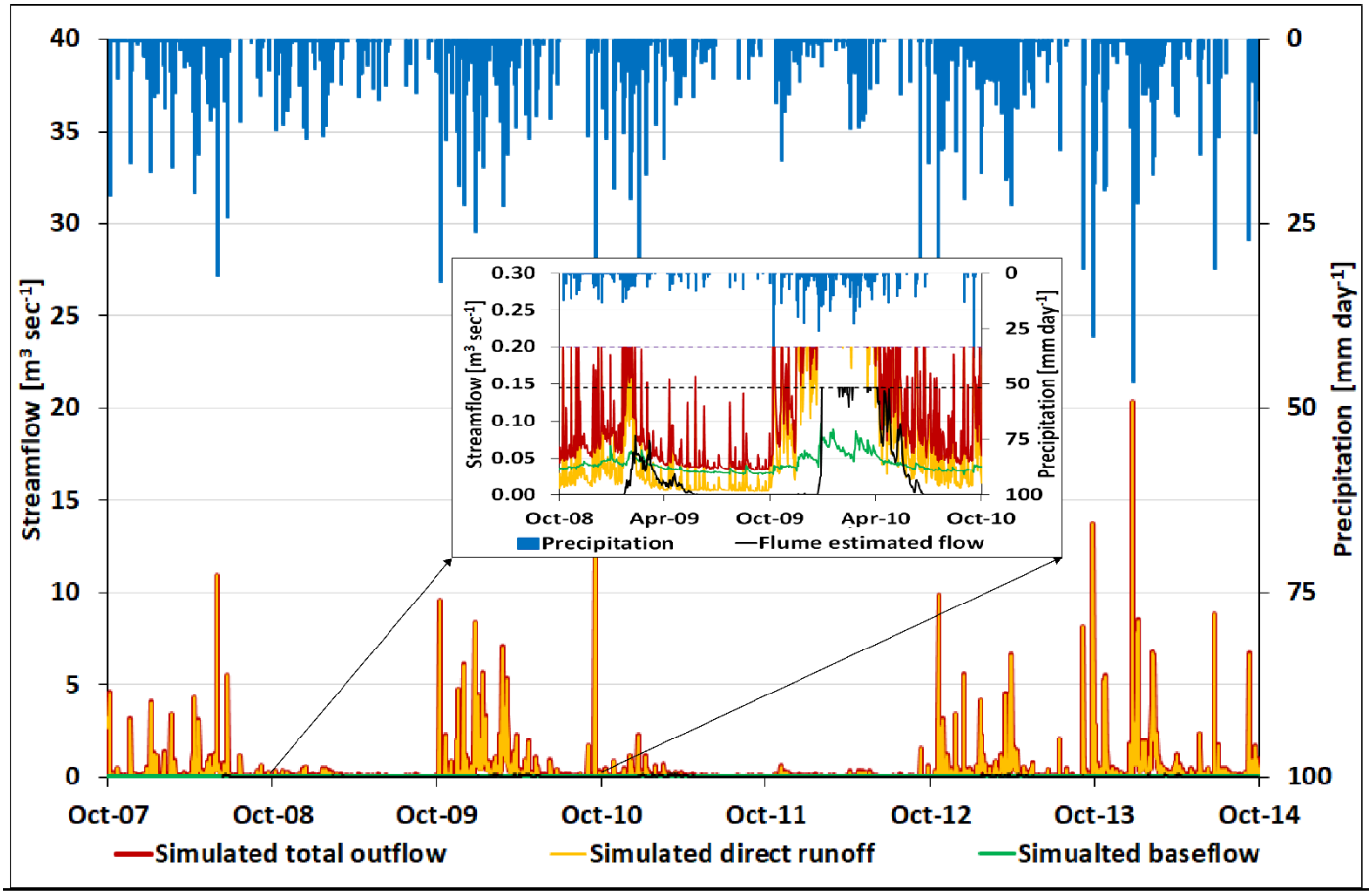

Fig. S5 Components of Sardon catchment daily outflow versus precipitation presented for the seven hydrological years studied, i.e. from 1 October 2007 to 30 September 2014; the zoom window presents flows in the dry year 2009 and in the wet year 2010. Note: (i) the flume-estimated flow is limited to 0.145 $m^3 s^{-1}$, as marked by *black dash horizontal line* and (ii) simulated total flow, and direct runoff are graphically restricted by *purple dash horizontal line* to < 0.2 $m^3 s^{-1}$ for visualization purposes

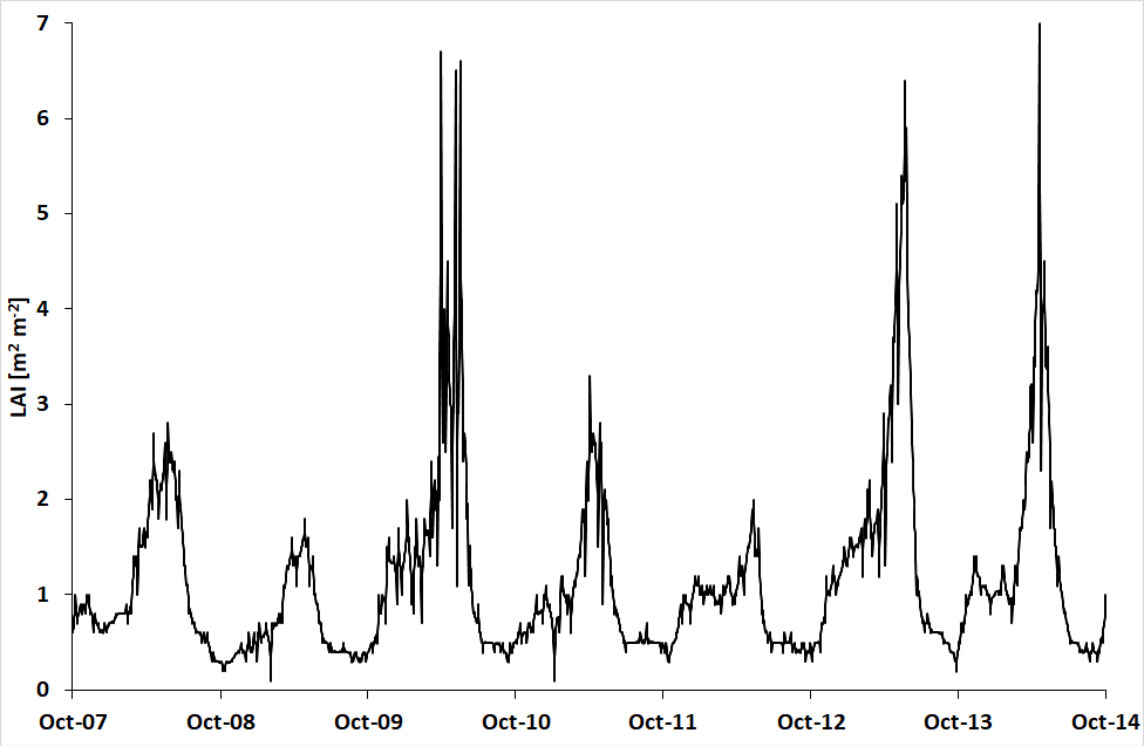

Fig. S6 Daily LAI of the seven hydrological years (1 October 2007 – 30 September 2014) for the land-cover class "grass/bare soil", as presented in Fig. 2 of the main article

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